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Basslink Monitoring Program

Gordon River Basslink Monitoring Annual Report

2004-05

Prepared by

Hydro Tasmania

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Executive Summary

The Gordon River Basslink Monitoring Annual Report is the primary output from Hydro Tasmania's Gordon River Basslink Monitoring Program. The principal objective of the report is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program during the 2004-05 reporting year.

2004-05 was the fourth year of pre-Basslink monitoring. The program will extend the knowledge gained during the 1999-2000 investigative years and the 2001-04 monitoring years on the present condition, trends, and spatial and temporal variability of the middle Gordon River environment. This information will assist in the future management of the river.

The results from the 2004-05 monitoring are reported in eight sections. Where appropriate, comparisons have been made with the data from earlier years. The information presented in this document is extracted from field reports produced by the various scientists employed to conduct the monitoring. The efforts of these researchers are duly acknowledged.

Hydrology

The 2004-05 year was drier than usual, with October, March and June recording 65, 48 and 29 %, respectively, of the average rainfall for each month at Strathgordon. The Strathgordon rainfall pattern echoed the state-wide pattern. Consequently, the power station often operated at full capacity during 2004-05, which resulted in greater three-turbine operation and less 0 and 1 turbine turbine operation than in 2003-04.

The power station operating regime, and hence the downstream hydrological regime, fell into three categories:

- intermittent operation, for July and August, and mid-September to end October 2004:
- operation at intermediate discharges (indicative of one-two turbine operations), from early to mid-September, early to mid-December 2004, early to mid-March and May, and most of June 2005; and
- operation essentially at full gate in late September, late October to mid-November 2004, , mid-December to early March 2005, mid-March to late April and from mid- to late May.

On a monthly basis, September, December and January exceeded the long-term median discharge values.

Overall, the power station discharge pattern was less than usual from the 30th to the 80th percentile, with a median value of 26 $m^3 s^{-1}$ compared with the long-term median value of 132 $m^3 s^{-1}$.

Analysis of the duration and frequency of shut down events indicated that there were 30 % more of these than in 2003-04, but with a similar modal range. No long-duration shut downs were recorded.

The power station recorded more short- and long-duration start-ups than in 2003-04. The modal range was 16-20 hours, similar to previous years.

The Gordon above Franklin (site 44) recorded a flow pattern which included the power station discharge plus some peak flow events produced by rainfall and tributary runoff. The data from this site showed that the flow pattern matched the power station tailrace discharge pattern closely from late October to late April. Natural high volume flow events originating in tributary streams were recorded in August 2004 and May 2005.

The duration curve for site 44 showed the overall effect of the natural inflows.

The median discharge values at the tailrace, site 65 and site 44 for 2004-05 were 26, 141, and 164 $m^3 s^{-1}$, respectively, showing the downstream increase due to inflows from tributary streams.

Water Quality

Surveys of water quality were undertaken on Lake Gordon and Lake Pedder during July and October 2004, as well as January and April 2005. The physico-chemical conditions of surface waters of Lakes Gordon and Pedder were considered normal for lakes in the region and water quality was high. One incidence of a low to moderate chlorophyll-*a* value was recorded at Boyes Basin during the summer (January) monitoring.

The thermal structure of the Lakes Gordon and Pedder were similar to those recorded in previous years.

Monitoring in the Gordon River included temperature at three sites (tailrace, 75, 62) and dissolved oxygen at the tailrace site. River temperatures displayed a broad seasonal pattern which was also related to the temperature of Lake Gordon. During periods of low discharges temperature differed between sites 75 and site 62. Under high discharge conditions, temperatures were similar at sites 75 and 62.

Dissolved oxygen concentrations were monitored at the tailrace and there were few periods when levels fell below 6 mg L^{-1}. High concentrations of 10-12 mg L^{-1} were associated with high power and variable power station output.

Fluvial Geomorphology

Basslink geomorphology monitoring in the middle Gordon River was completed in October 2004 and April 2005. Erosion pins and scour chains were measured at all sites by two boat based teams on each occasion, and repeat photo-monitoring was completed during the April trip.

Monitoring in October 2004 occurred under relatively high flow conditions, with water levels up to 1 m higher than usual during power station shut downs. Prior to the monitoring, discharge from the power station had been infrequent and relatively low. In April, the power station had been operating at 3-turbine discharge for several days prior to monitoring, resulting in saturated banks. During both monitoring trips, field observations reflected the flow conditions and preceding power station operating patterns. In October the deposition of fine muds and organic debris on banks in all zones was common, due to deposition associated with natural flow events during the power station shut down. In April 2005 this deposition was absent in zones 1 or 2, and seepage erosion processes were active. Piezometer results show that in-bank water surface slopes exceeded 0.1 during this period, consistent with previous results and the present understanding of seepage processes.

Monitoring in the middle Gordon River was expanded during the 2004-05 year to increase the number of erosion pins in the 2-3 turbine bank level, and at the 55 $m^3 s^{-1}$ bank level, in anticipation of the introduction of an environmental flow. Bank profiles at all sites were also obtained during 2004-2005 which will be used to assist in the interpretation of post-Basslink monitoring results.

Erosion pin monitoring results were consistent with previous results and the understanding of seepage and scour processes operating in the middle Gordon River.

Overall, the monitoring results from this past year are consistent with the long-term findings, namely: Zone 1 is relatively stable, zone 2 has high levels of activity in the 1-2 and 2-3 bank levels, with the most active sites at the downstream end of the zone. In contrast, zone 3 is most active at the upstream end of the zone, where it is affected by power station flows, inflows from the Orange River and backwater effects from the Denison. Zone 4 shows relatively constant rates of toe erosion, and both zones 4 and 5 show high variability, but overall low rates of erosion or deposition above the 1-turbine bank level.

Karst Geomorphology

Karst monitoring was conducted and water level data loggers were downloaded in October 2004 and April 2005. Water levels were considerably lower in April 2005 than in October 2004 when two erosion pins at Kayak Kavern could not be located. A solutional opening in dolomite was noted from the river near the GA-X1 cave. This feature would normally be below water level and may provide a pathway for movement of water between the cave and the river.

In the Bill Neilson Cave, the seasonal pattern of winter erosion followed by summer aggradation of sediment has continued on the lower slopes of the first and second wet banks due to the action of the cave stream under higher energy winter flow conditions. In contrast, modest or negligible sediment movement occurred at higher levels on the same sediment banks. There was zero change at the dry sediment bank further into the cave during the summer and winter periods. These findings are similar to the 2003-04 results and for most of the period since monitoring commenced.

In Kayak Kavern, the upper surface of the sediment mound experienced erosion in both winter and summer for 2004-05. The erosion pattern detected in October was contrary to that of the winter period of 2003 when deposition occurred. In contrast, the lower slopes have been subject to slumping and aggradation with 64 mm of sediment accumulating at Pin 17 during 2004-05. Results obtained to date point towards episodic sediment fluxes rather than distinct seasonal trends.

In cave GA-X1, net erosion within the active levels during winter was measured in October, in contrast to previous winters which have predominantly been periods of deposition. This is considered to be due to the higher percentage of time that the river water level was fluctuating within the cave relative to previous years. The April data indicated no loss of sediment at the lower or upper levels but there was minor erosion recorded at the mid level. The erosion at the mid level is likely to be due to the fluctuating Gordon River water levels in the cave at or about this level. These results are consistent with a pattern of slow change typically in the direction of surface lowering which is evident in the data since monitoring commenced.

Erosion pins at the dolines at Sites 3 and 4 generally showed an increase in debris over summer. Material is generally accumulating towards the bottom of the features. At Site 3 this contrasts with a reduction in the height of debris recorded for most pins in the preceding winter measured in October, whereas at Site 4 the winter period was one of accumulation. Consistent with previous trips, measurement of distances between the tops of the pins at Sites 4 and 5 indicated no significant changes within the precision of the method which suggests that the morphology of the dolines has remained stable since the program commenced.

The two erosion pins at Channel Cam recorded significant erosion of 9–13 mm over the summer period, in contrast to the previous winter, which is likely to be due to the relatively high proportion of time the channel was inundated due to the 3-turbine operations.

Riparian Vegetation

Riparian vegetation surveys were conducted in October 2004 and April 2005. Data collected in 2005 showed that the existing vegetation to be highly stratified up the banks of the river in response to varying degrees of flow-induced disturbance. The bank below the regulated water level had reduced abundance and cover of trees and shrubs in smaller size classes and ground cover species. The extant vegetation contained predominatly larger tree species that were able to resist mechanical disturbance and continue to photosynthesize during high flows.

Photo-monitoring over the 2002-05 monitoring period showed that *Leptospermum riparium*, a species that is morphologically adapted to inundation is showing signs of decline with reduced canopy and cover apparent. Ferns also decreased significantly over the baseline monitoring period on the bank below the regulated water level. Grasses, herbs and graminoids had limited cover at the regulated water level. Grouped vegetation cover and total bare substrate data did not show any significant trends in the banks below the regulated flow level.

The banks above the the regulated water levels had increased abundance of tree and shrub species in smaller size classes and ground cover species. Species richness is higher than that below regulated flow levels and most life forms are well represented. Total vegetation cover fluctuated significantly between the zones and the years. The differences in abundance and cover of vegetation between the bank above and below flow regulation are a product of disturbance removing vegetation and also the natural processes of seedling recruitment and persistence.

Size class analysis of seedling recruitment showed that while germination does occur in most areas including the highly impacted areas below the Plimsoll line, seedlings do not persist. Periodic waterlogging, inundation and localised scour and mechanical disturbance prove too frequent or intense to allow continued growth. This pattern is less severe, but still apparent at the last monitoring site which is 32 km downstream of the tailrace.

Dieback of *Richea pandanifolia* (pandani) was recorded in many areas along the middle Gordon River from Abel Gorge down to the Franklin River confluence. This species is highly susceptible to the pathogen, *Phytophthora cinnamomi, c*ommonly known as dieback. *P. cinnamomi* analyses were undertaken at 14 vegetation monitoring sites along the Gordon River and at the Knob helipad. The results showed that the disease was present at many sites in all zones along the river. Extant *Phytophthora* hygiene procedures have been updated and appropriate managmenet strategies are being developed.

Some areas of *R. pandanifolia* dieback have tested negative to *P. cinnamomi* and localised scour and physical disturbance is more likely to have caused this dieback.

Macroinvertebrates

Macroinvertebrates were sampled in October 2004 and April 2005 at nine sites in the Gordon River between the Gordon Power Station and the Franklin River junction.Six reference sites were also sampled in the Franklin, Denison, Maxwell and Jane Rivers. Sampling involved both quantitative surber samplers and rapid bioassessment on-site.

Overall patterns of diversity, community composition, abundance and O/E values followed the same trends recorded in previous years. The number of taxa increased with distance downstream of the power station. O/E values also increased with distance from the power station with values upstream of the Denison River falling significantly below reference values. Paired *t*-tests of O/Epa and O/Erk values for all sites did not suggest a significant change between this survey and those conducted previously (all with $p > 0.1$). This indicates that no consistent or substantial change in O/E values had occurred across all sites between any of these dates.

Analysis of all macroinvertebrate monitoring data to date indicates no statistically significant or substantial change in the pattern of O/E values, number of taxa or total macroinvertebrate abundance between years 1 and 4 of pre-Basslink monitoring.

Algae

Benthic algae were sampled in October 2004 and April 2005. Patterns and trends in algal cover were broadly similar to those observed in previous years, including:

- Moss and filamentous algae having similar, low overall mean % cover across all sites. The mean percentage cover of moss and filamentous algae ranged between 0.23-13.79 % and 0-19.68 %, respectively for October and April.
- Filamentous algae being more abundant at sites 75 to 69 than at other sites;
- Characeous algae comprising of Nitella/Chara were observed at sites 74, 72, 63 and 57 at less than 2.64 % mean cover
- Mean moss cover was highly variable between sites 42-75.
- Macrophytes only occurring at site 72 and at low densities with a mean cover of 0.01 %.

Fish

The fish monitoring study was undertaken in December 2004 and April 2005. Catch rates for brown trout were similar to previous surveys, dominating the total mean Catch Per Unit Effort (CPUE) for the survey, and dominating catches in tributary sites of zones 2-4, river sites of zones 2-3, and the upper Henty river site. Redfin perch abundance was relatively low, and the species does not appear to have increased its distribution in the river.

Pouched lamprey ammocoetes were in moderate abundance during both summer and autumn surveys, whilst only a single short-headed lamprey was captured during April 2005. Pouched lampreys were collected from zone 2 river and tributary sites, re-confirming the species ability to negotiate the hydraulic barrier of the Splits.

Short finned eels showed a wide distribution throughout the test and reference zones during the 2004-05 surveys. Summer catches were generally higher than those recorded in the autumn survey. Summer catch rates from the Birches Inlet sites were higher than those recorded for previous surveys.

Strong juvenile recruitment was evident in the summer galaxiids catches. Jollytails, climbing galaxias, and particularly spotted galaxias abundances were particularly high in the downstream reaches of the Franklin, Gordon and Henty Rivers. Jollytails were absent and climbing galaxias abundance declined significantly in the autumn survey, whilst juvenile spotted galaxias were still evident at the lower Gordon and Henty sites, reflecting the propensity of climbing galaxias to migrate further upstream into the catchment.

Tasmanian mudfish continued to be present at the downstream Henty River site during the summer sample, and a single Australian grayling was also collected from this site.

Interdisciplinary linkages

It is evident that interactions between disciplines are important for investigating underlying processes and for a better understanding of the monitoring results. The hydrological regime is a consistent factor affecting all sites downstream of the power station. Flow regulation tends to dominate the flow regime of the downstream sites with a pattern which is often substantially different from the natural flow regime.

Interactions between disciplines are not necessarily discernible over a one-year timeframe, hence their relatively brief treatment in this report. The Basslink Baseline Report includes a comprehensive discussion and examination of interdisciplinary linkages through the development of a conceptual model of the processes and characteristics of the middle Gordon River. The Basslink Baseline Report is due to be produced in early 2006.

Contents

1 Introduction and background

The purpose of the Gordon River Basslink Monitoring Annual Report (GRBMAR) is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program (BMP) during 2004-05.

1.1 Context

The fundamentals of the Basslink Monitoring Program (BMP) were established as outcomes of the Basslink approvals process. The BMP has been designed to provide the information needed to assess Basslink-related impacts. The aims of the Basslink Monitoring Program are:

- To undertake pre-Basslink monitoring in order to extend the understanding gained during the 1999-2000 investigative years on the present condition, trends, and spatial and temporal variability of potentially Basslink-affected aspects of the middle Gordon River ecosystem;
- To undertake six years of post-Basslink monitoring in order to determine the effects of Basslink operations and to assess the effectiveness of mitigation measures; and
- To obtain long-term datasets for potentially Basslink-affected aspects of the middle Gordon River ecosystem, which will allow refinement of theories and more precise quantification of spatial and temporal variability, processes and rates.

The focus of the pre-Basslink monitoring program has been to measure conditions under the presently existing operating regime, rather than attempting to relate them to ‘natural’ or ‘pristine’ conditions. This approach is an essential element of the monitoring program given the highly modified conditions which presently exist due to the presence of, and the flow regulation resulting from, the middle Gordon Power Scheme.

In terms of World Heritage values, the modified conditions in the Gordon River have been explicitly recognised throughout the World Heritage nomination and management activities and the Basslink approvals process. Kriwoken (2001) documented the specific points that:

- the production of hydro-electricity significantly and extensively impacted South-west Tasmania, and in particular the Gordon River, four years before the region was first nominated as a World Heritage Area. The Gordon River was therefore a regulated, highly modified river environment and not representative of a pristine ecosystem when listed under the World Heritage Convention;
- the 1982 and 1989 World Heritage Area nominations expressly acknowledge existing hydro-electric schemes and the direct impact those schemes have on natural waterways in the Tasmanian Wilderness World Heritage Area (TWWHA). Implicit in this acknowledgement is that downstream ecosystems are modified by flow regulation; and

- Lake Gordon, the Gordon River Power Station and the tailrace were not included in the TWWHA.

There has been some feedback from stakeholders associated with the BMP suggesting that a much broader, whole-of-catchment approach would be a more appropriate resource management paradigm for the BMP to adopt.

The raft of independent investigative studies produced for the Basslink IIAS (see Locher 2001) led, via the comprehensive approvals process, to the formulation of the BMP and its requirements. These were included in the Special Licence which Hydro Tasmania holds under the *Water Management Act* 1999. The constraints on the BMP are appropriate for the task at hand (as defined in the Special Licence) given the physical limitations of the area, the climate and the resource constraints of the Basslink project.

1.2 Basslink Baseline Report

One of the requirements of Hydro Tasmania's Special Licence is to produce a Basslink Baseline Report (BBR) prior to Basslink commencement. The BBR will provide a comprehensive statement of pre-Basslink conditions in the middle Gordon River. This will involve the analysis of all of the BMP data collected to date and the application of the results of these analyses to the consideration of how post-Basslink conditions will be compared with the pre-Basslink ranges of variability and trends. This work is due for completion in early 2006. The Basslink Baseline Report will be a public document.

1.3 The 2004-05 monitoring program

The Gordon River Basslink Monitoring Program for 2004-05 completed the fourth year of pre-Basslink monitoring. Monitoring took place in October and December 2004 and in April 2005. Poor weather and high tributary flows in early April 2005 meant that some of the work was postponed for a week.

Aerial photos of the Gordon River were taken in December 2004, under flow conditions similar to a previous aerial photography survey completed in 1999. The results of photogrammetric analysis will be presented in the 2005-06 GRBMAR.

1.4 Logistical considerations

As indicated in the 2001-02 GRBMAR, access presents significant challenges in this part of the Tasmanian Wilderness World Heritage Area. On-site monitoring activities require helicopter support, due to the density of the terrestrial vegetation and the absence of access infrastructure.

Power station outages are needed because the majority of viable helicopter landing sites are on cobble bars in the river bed which are exposed only when there is little or no discharge from the power station. They are also required because most of the biotic and geomorphic monitoring activities require measurements or sampling to take place within the river channel, which would not be possible under high flow conditions.

To complete the required monitoring work, the Gordon River Basslink Monitoring Program has a schedule of four visits per year, each involving two consecutive days of power station outage.

1.5 Geographic datum

Map coordinates given in this document use the 1966 Australian Geodetic Datum (AGD) as this corresponds with the topographic maps currently available for the area. A later datum, the Geocentric Datum for Australia (GDA), has recently been adopted. Site references using the AGD will be approximately 200 m different from those using the GDA. These will be updated as new maps become available.

1.6 Document structure

This document is the fourth of the Gordon River Basslink Monitoring Annual Reports to be produced, and is organised into eleven sections plus an executive summary, similar to earlier editions.

This first section discusses the requirements, context, operational considerations and constraints of the program. Sections 2 - 9 report on the monitoring work which was undertaken during 2004-05, and present the consolidated results of each of the individual monitoring elements. These include:

- Hydrology (section 2);
- Water quality (section 3);
- Fluvial geomorphology (section 4);
- Karst geomorphology (section 5);
- Riparian vegetation (section 6);
- Macroinvertebrates (section 7);
- Algae (section 8); and
- Fish (section 9).

The results from the 2004-05 monitoring are reported in each of these sections. Some between-year analyses were undertaken, where sufficient data were available to make such analyses meaningful. A more complete analysis of variability and time-related trends within the Gordon River ecosystems under study will be reported in the Basslink Baseline Report.

Section 10 briefly discusses the interdisciplinary linkages which are likely to be in operation in the middle Gordon River, while section 11 lists the reference material used in this report.

1.7 Authorship of field reports

The information presented in sections 2- 9 was extracted from field reports produced by the various scientists employed to conduct the monitoring, as shown in Table 1.1. The efforts, and original contributions, of these researchers are duly acknowledged.

This document was prepared by David Blühdorn and Rudi Regel, with considerable assistance from the researchers and internal reviewers, including Helen Locher. Donna Porter assisted with editing and production.

Table 1.1. Section numbers, section titles and original authors from whose field reports the information in sections 2 – 9 was extracted.

Section	Section title	Author(s)
2	Hydrology	David Blühdorn and Wes Jeffries (Hydro Tasmania)
3	Water quality	David Blühdorn (Hydro Tasmania)
4	Fluvial geomorphology	Lois Koehnken (Technical Advice on Water)
5	Karst geomorphology	Jenny Deakin and Rolan Eberhard (consultants)
6	Riparian vegetation	Anita Wild (Hydro Tasmania)
7	Macroinvertebrates	Peter Davies and Laurie Cook (Freshwater Systems)
8	Algae	Peter Davies and Laurie Cook (Freshwater Systems)
9	Fish	David Andrews (Hydro Tasmania)

1.8 Site numbers

Throughout this report, monitoring locations are identified by site number. These represent the approximate distance upstream from the Gordon River mouth at the south-eastern end of Macquarie Harbour. The monitoring work is conducted between sites 39 (immediately downstream of the Franklin River junction, at the upstream tidal limit) and site 77 (the power station tailrace).

Some disciplines, such as fluvial geomorphology and riparian vegetation, use zones rather than the standard site numbering system. This is because their work is associated with longer reaches of riverbank than are suitable for the 'site' nomenclature. The fish monitoring uses both systems. Site numbers define the specific monitoring location and fish zones define the river reach to which the sites belong.

In the macroinvertebrate section (Section 7), some figures use 'distance from the power station' to better illustrate the point being made. Site numbers can be determined, if necessary, by subtracting 'distance from power station' from 77.

2 Hydrology

This part of the Gordon River Basslink Monitoring Annual Report summarises the hydrological data from the Gordon River downstream of the Gordon Power Station for the 2004-05 period.

2.1 Site locations

The gauging stations used to record river levels during 2004-05 are shown in Figure 2.1. These were sites 39, 44, 62, 65, 69, 71, 75 and the Gordon Power Station tailrace (site 77).

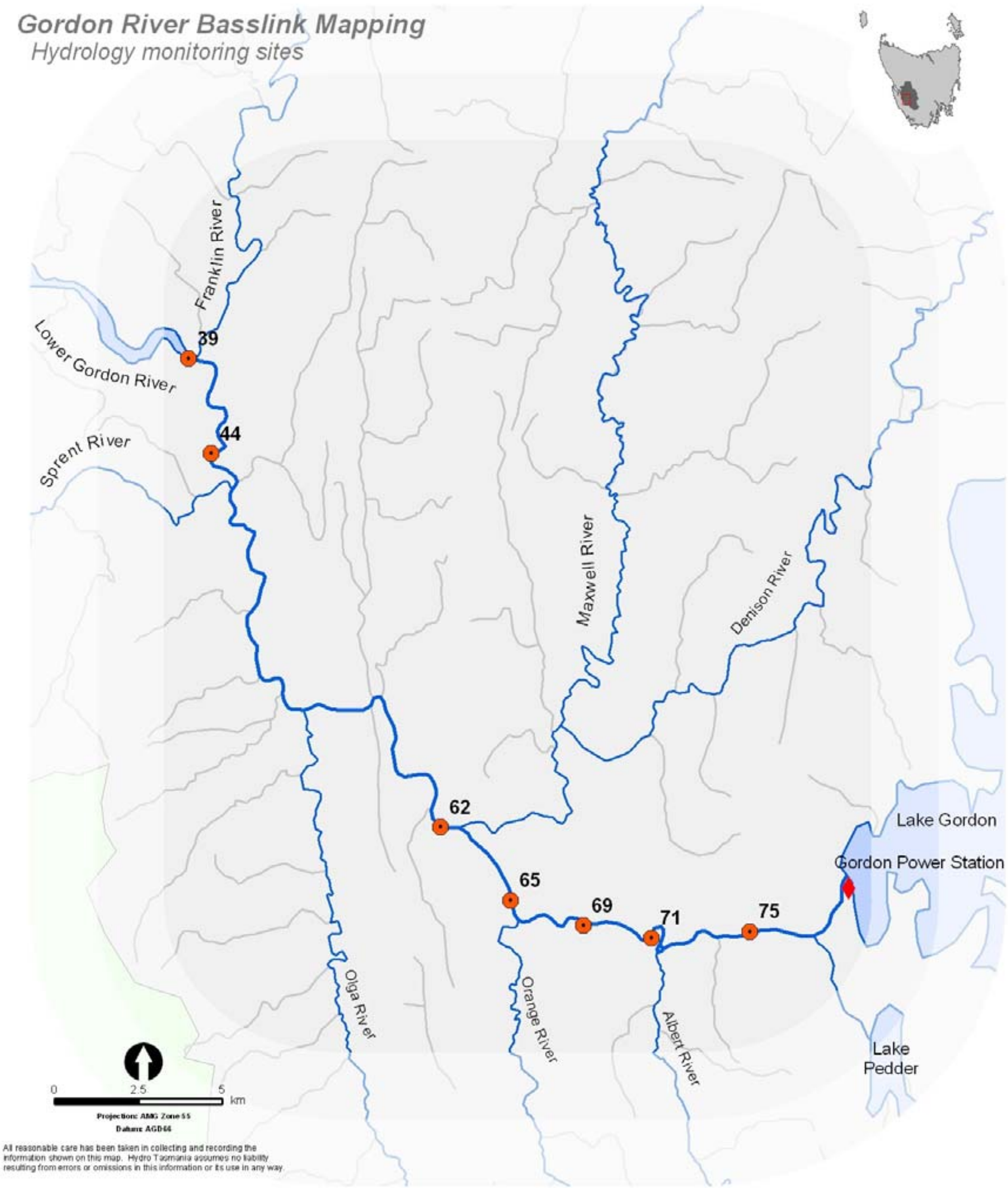


Figure 2.1. Location of the water level recorders in the middle Gordon River.

2.2 Strathgordon rainfall

The Strathgordon meteorological station has rainfall records dating back to 1970. These allow the development of long-term mean monthly values and comparisons with the monthly rainfall totals recorded for 2004-05. Figure 2.2 shows the total monthly and long-term average rainfall values. These indicated that 2004-05 was a dry year, recording less than the 20th percentile of the long-term annual rainfall. October 2004, February 2005 and June 2005 were dry months, with values lower than the 20th percentile of the long-term values for those months.

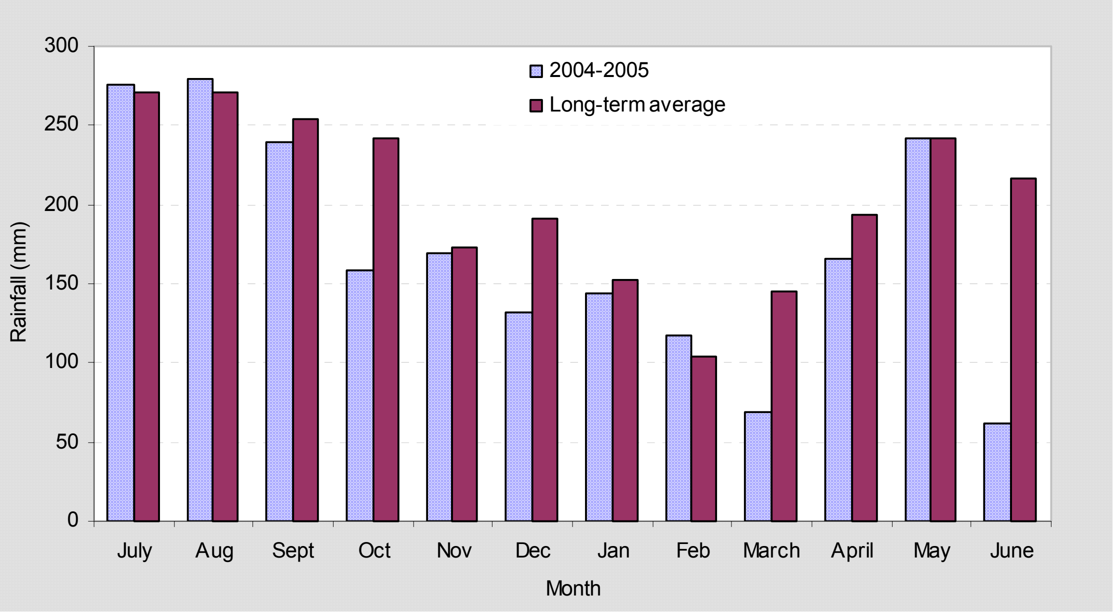


Figure 2.2. Total monthly rainfall values recorded at Strathgordon for 2004-05 compared with mean monthly values from 1970-2005.

2.3 Gordon Power Station discharge

The discharge pattern for the Gordon Power Station is driven by factors other than local rainfall. With the year being dry state-wide, the Gordon Power Station was utilised more often than under usual rainfall conditions.

2.3.1 Discharge

Figure 2.3 shows the discharge from the power station for 2004-05. It indicates a period of intermittent power station operation from July to early September, and from mid-September to late October 2004. The power station operated under high discharge conditions in mid-September and from early November until late April 2005 after which a more-intermittent operating pattern began which lasted until the end of June.

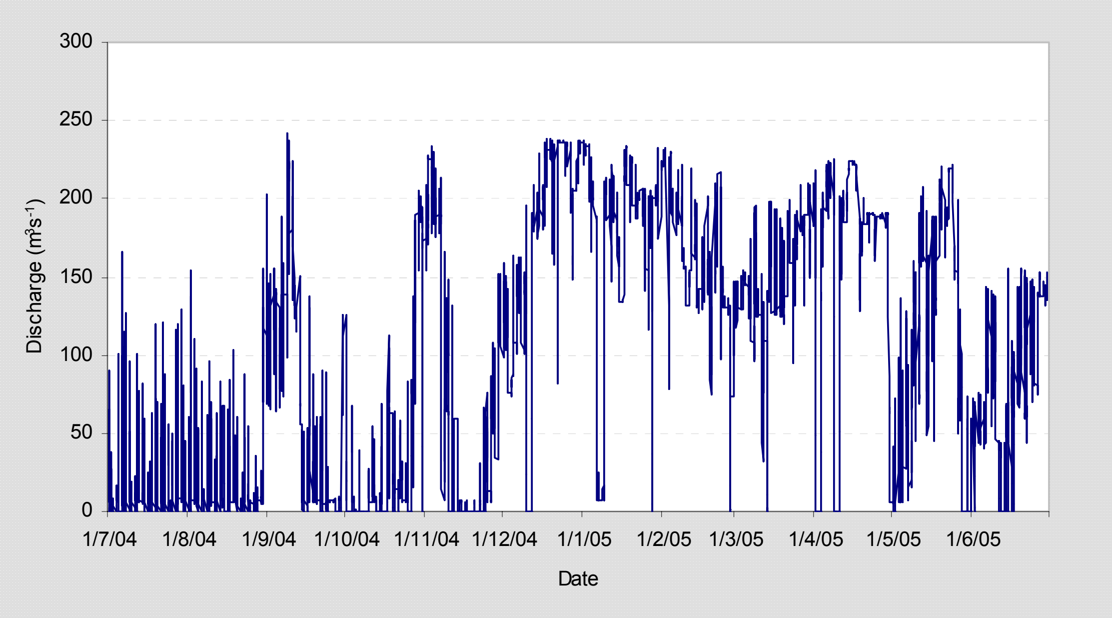


Figure 2.3. Gordon Power Station discharge (hourly data) from July 2004 to June 2005.

During 2004-05, the power station was shut down less and operated 2 or 3 turbines more than 60% of the time (Table 2.1). This was a substantial increase over the 2003-04 operations, and reflected the generally drier conditions across the state.

Table 2.1. Percent of time that each configuration of turbines was in operation during 2004-05.

Configuration	**Percentage of time operating**	**Approximate tailrace discharge ($m^3 s^{-1}$)**
0 machines running	14.7%	0-10
1 machine running	24.8%	70-80
2 machines running	22.5%	140-150
3 machines running	37.9%	>210

2.3.2 Median monthly discharge

Figure 2.4 shows the median monthly discharge from the power station for 2004-05 compared with long-term values (since August 1996). This figure illustrates that discharge was lower than usual for July and November 2004, and February, March and May 2005. It was higher than usual in September and December 2004 and in January and June 2005.

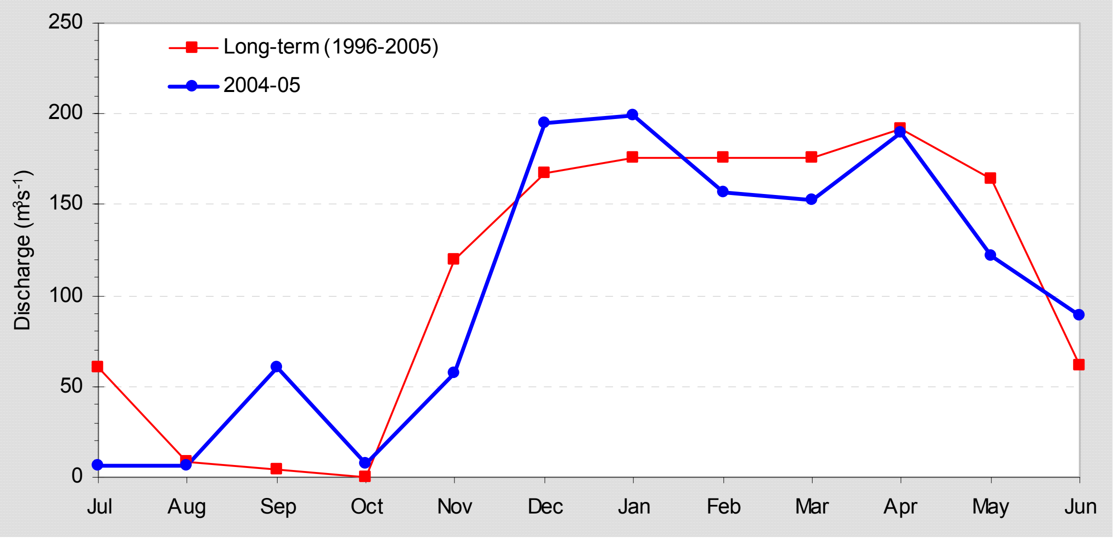


Figure 2.4. Median monthly discharge from the tailrace of the Gordon Power Station for 2004-05 compared with long-term median values.

2.3.3 Duration curves

Figure 2.5 shows the duration curve for the power station tailrace discharge for 2004-05, as well as the long-term (since 1996) duration curve. The 2004-05 curve shows that there was less discharge than usual from the 24th to the 83rd percentile, with the greatest difference occurring around the median value. The long-term median value was around 132 $m^3 s^{-1}$, while the 2004-05 median value was 26 $m^3 s^{-1}$. This pattern is not greatly dissimilar from the previous year, except for the higher volume discharges (1st to 23rd percentiles), which were greater than in 2003-04.

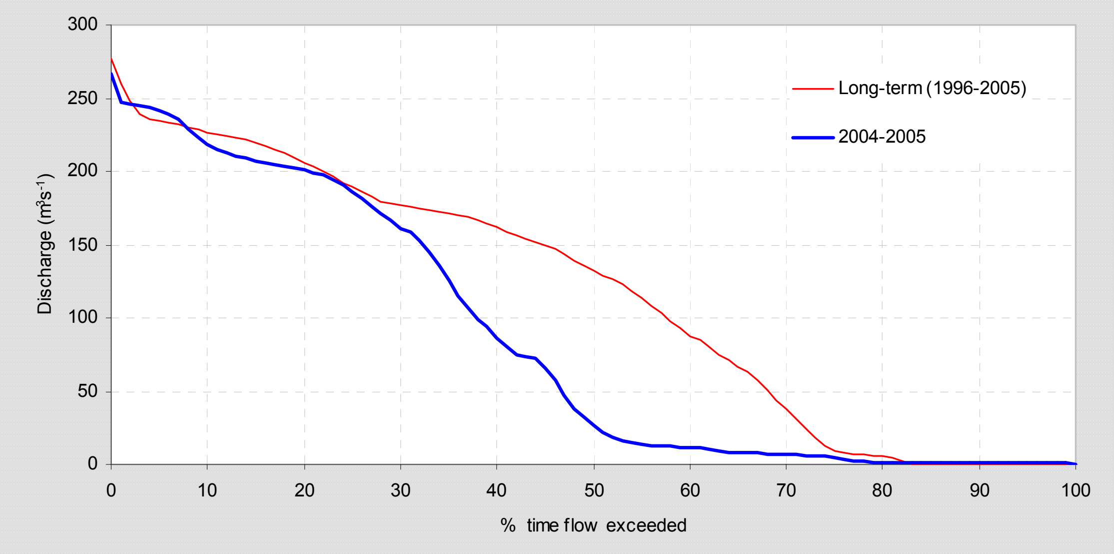


Figure 2.5. Duration curve for discharge from the power station tailrace for 2004-05.

2.3.4 Event analyses

One of the methods for analysing power station operations and their effect on discharge into the Gordon River is to examine the number and duration of shut down (zero discharge) and operating (>zero discharge) events.

In 2004-05, the shut down events had a distinct mode of 5-7 hour durations. This was a similar modal range to previous years, although the frequency of 6 hour outages was much greater (24 events vs. 12). Figure 2.6 shows the frequency and duration of the shut down events. In total, 100 shut down events were recorded during the year, an increase from the 71 events of 2003-04. No long-term outages (>144 hours) were recorded.

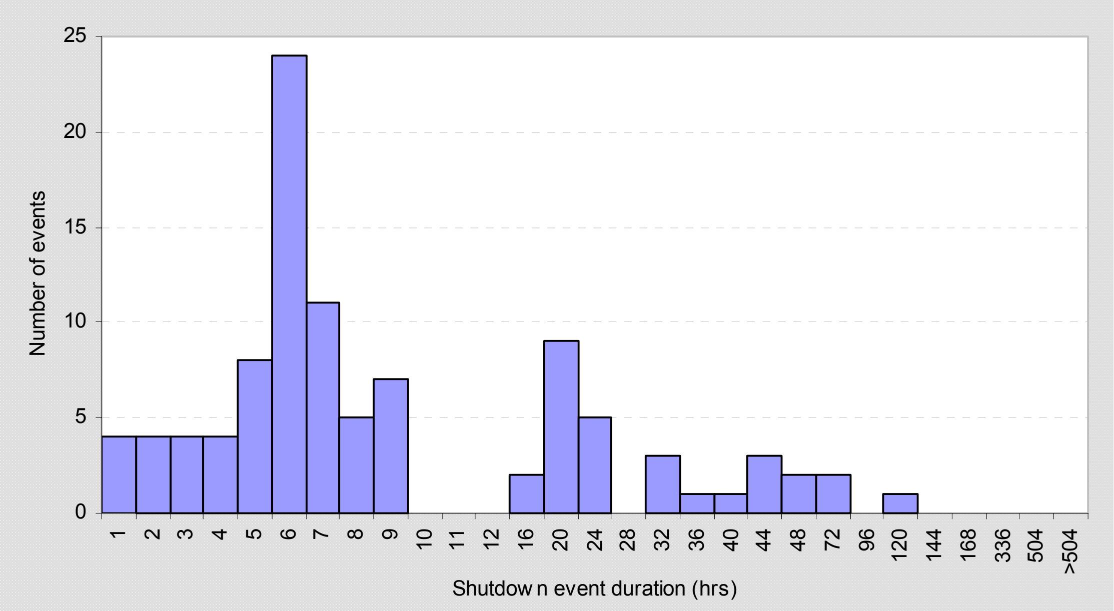


Figure 2.6. Frequency and duration of zero discharge (shut down) events recorded for the Gordon Power Station during 2004-05.

The number of operating events, indicated by discharges greater than 3 $m^3 s^{-1}$, is shown in Figure 2.7. This figure indicates that there were a comparatively large number of 16-24 hour operating events, a similar modal value to previous years. Although the number of short-duration operating events was greater than in 2003-04, there were also more long-term operating events. This pattern reflects the greater utilisation of the power station during 2004-05.

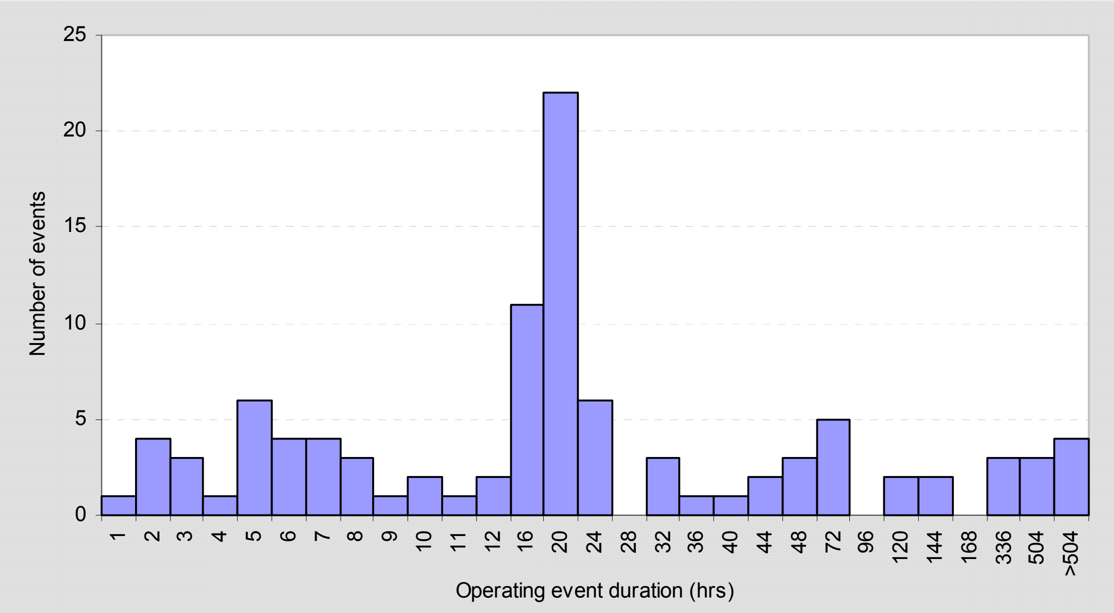


Figure 2.7. Frequency and duration of operating events (discharge > 3 $m^3 s^{-1}$) recorded for the Gordon Power Station during 2004-05.

2.4 Gordon above Denison (Site 65)

Site 65, about 2 km upstream of the Denison confluence, was installed in early 2004 in preparation for Basslink commencement. It will monitor the minimum environmental flow which will be provided after Basslink commencement.

2.4.1 Discharge

Figure 2.8 shows the discharge recorded at site 65 for 2004-05. These data indicate a close concordance with power station discharge (Figure 2.3), to which peak values, the result of high flows from tributary streams, such as the Albert and Orange Rivers were added.

A backwater effect has been observed at this site. When the Denison floods and Gordon discharge is low, the Denison water may backflow up past site 65. The result of this effect would be an overestimation of the high flows at site 65. The primary function of this site is to monitor the minimum environmental flow, so the backwater effect will not interfere with this function as it only occurs during periods of high tributary flow (i.e. when the minimum environmental flow would not be required).

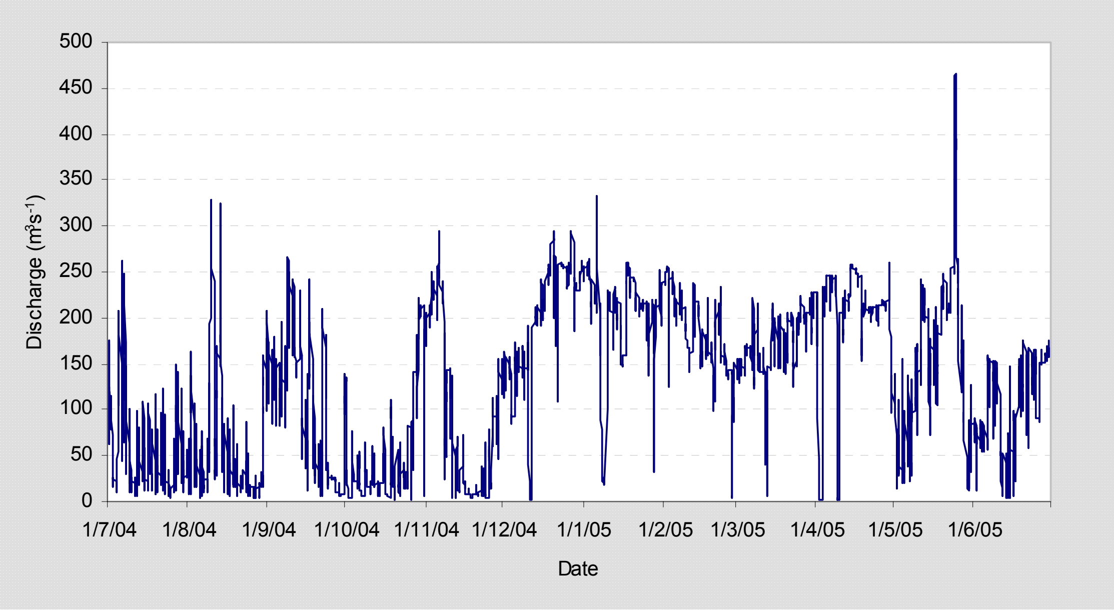


Figure 2.8. Flow recorded (hourly data) at site 65 (Gordon above Denison), from July 2004 to June 2005.

2.4.2 Median monthly flows

The median monthly flow for site 65 is shown in Figure 2.9. No comparison with previous (historic) patterns is made because the site is new. Comparison with the tailrace discharge for 2004-05 shows an identical pattern, but at slightly higher flow values.

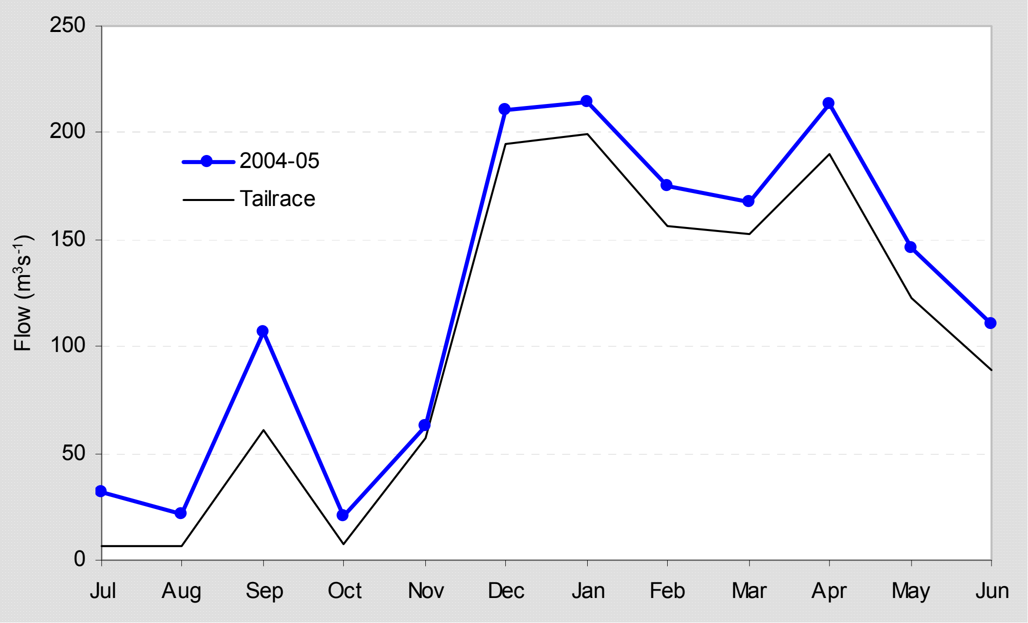


Figure 2.9. Median monthly flow at site 65 and the tailrace for 2004-05.

2.4.3 Duration curves

The duration curve for site 65 is shown in Figure 2.10. No historic flow data are available for this site. Comparison with the tailrace duration curve for 2004-05 shows that the unregulated rivers apparently contributed substantial additional flows between the 40th–70th percentiles. Some of this may be attributable to backflow effects from the Denison River. The extent of this possible artefact is difficult to determine without discharge data from the Denison River.

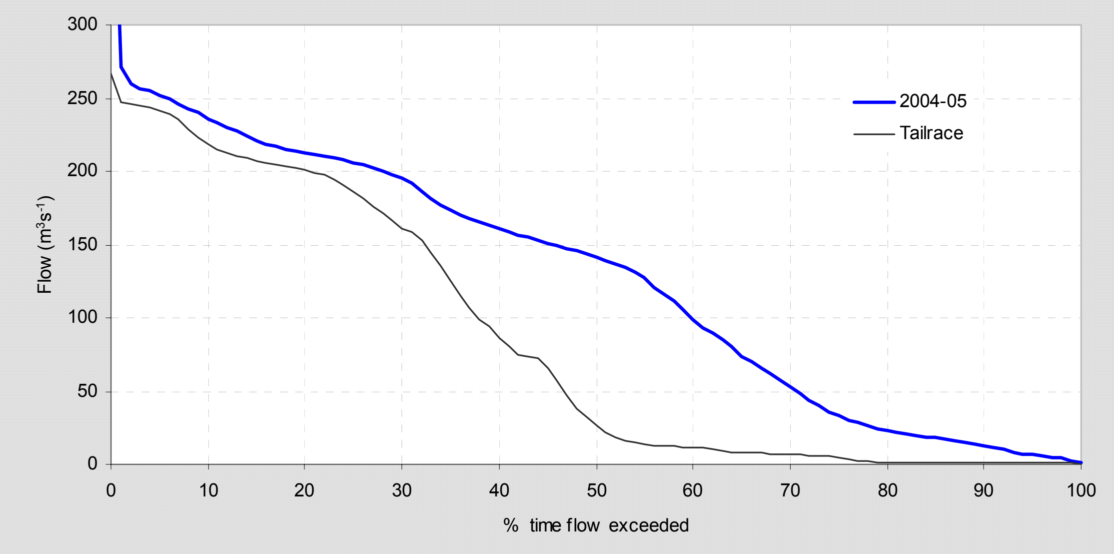


Figure 2.10. Duration curve for flow at site 65 and the tailrace for 2004-05.

2.5 Gordon above Franklin (Site 44)

The Gordon above Franklin site (site 44) is the furthest downstream site unaffected by tidal influences. Site 44 records the power station discharge after 33 km of flow in the existing river bed. This is mixed with the discharge from a number of significant tributaries, including the Albert, Orange, Denison, Maxwell, Olga and Sprent Rivers. It does not include flows in the Franklin River. Data from site 44 were used to indicate the effects of tributary streams on the discharge pattern from the power station.

2.5.1 Flow

Figure 2.11 shows the time series plot for flow at site 44 for 2004-05. The power station discharge is superimposed. For much of the year, the power station discharge is the major component of the site 44 flows, most evident during the period from late October through to the end of April. Overlying this is the flow from tributary streams, such as the Denison River, giving the high peak discharges evident in Figure 2.11. Peak flows occurred in August 2004 and late May 2005.

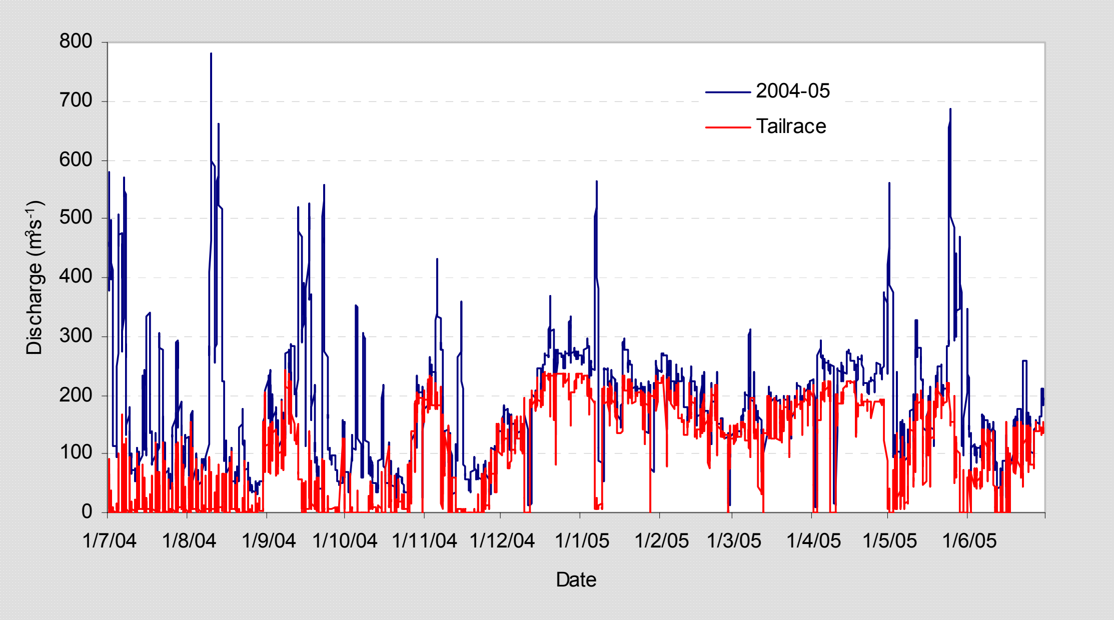


Figure 2.11. Flow recorded (hourly data) at site 44 (Gordon above Franklin) and the tailrace during 2004-05.

2.5.2 Median monthly flows

Figure 2.12 shows the median monthly discharge for this site over 2004-05, compared with the long-term (since December 1999) pattern. It indicates that discharge pattern at the downstream end of the study area was similar to historic. The pattern tended to mimic that of the Gordon Power Station discharge (Figure 2.4) over the spring-summer months, while showing the additional contribution of natural inflows in the autumn-winter months.

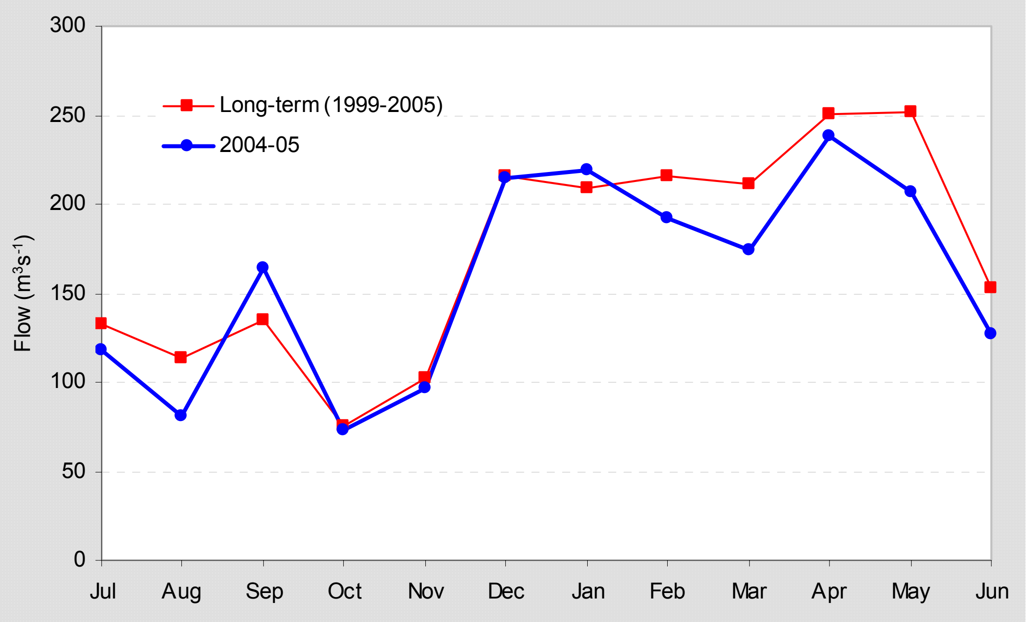


Figure 2.12. Median monthly flow at site 44 (Gordon above Franklin) for 2004-05 and the long-term monthly median values.

2.5.3 Duration curves

Figure 2.13 shows the duration curve for Gordon River site 44 (upstream of the Franklin River) for 2004-05 and compares it with the historic (since December 1999) record. It shows that, for this year, site 44 recorded slightly lower discharge than historic, from the 5th to the 70th percentile.

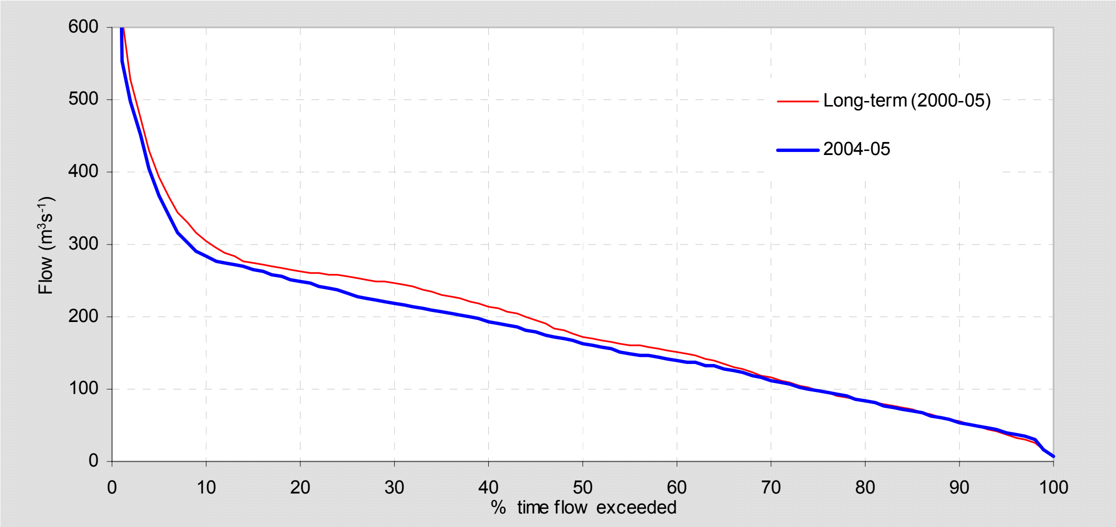


Figure 2.13. Duration curves for the Gordon above Franklin site (site 44) for 2004-05 and historic (since 2000).

Figure 2.14 shows the duration curves for sites 44, 65 and the tailrace with the Y axis scaled to match that of the tailrace duration curve (Figure 2.5). This allows a more accurate comparison between the three sites, and shows that the pattern of low discharges evident at the tailrace and, to a lesser extent, site 65 was not apparent at site 44. This indicates that the tributary streams were making a substantial contribution throughout the year at this site. Site 44 also recorded much greater flood discharges than the upstream sites, as would be expected.

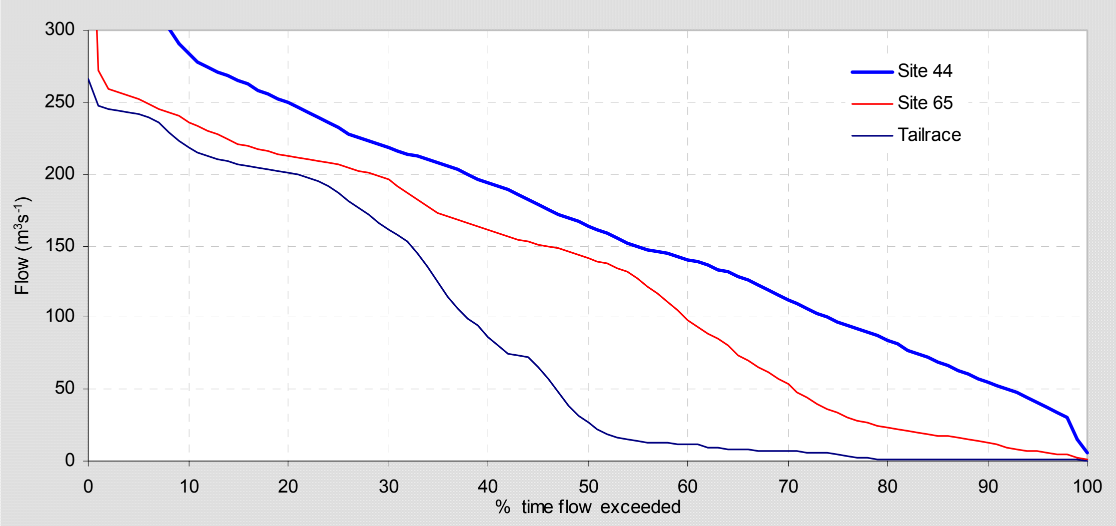


Figure 2.14. Duration curves for site 44 (Gordon above Franklin), site 65 (Gordon above Denison) and the tailrace (site 77) for 2004-05.

2.6 Conclusion

The 2004-05 year was drier than usual, with October, March and June recording 65%, 48% and 29%, respectively, of the average rainfall for each month. The Strathgordon rainfall pattern echoed the state-wide pattern. Consequently, the power station often operated at full capacity during 2004-05, which resulted in greater three-turbine operation and less 0 and 1 turbine operation than in 2003-04.

The power station operating pattern, and hence the downstream hydrological regime, fell into three categories:

- intermittent operation, for July and August, and mid-September to end October 2004:
- operation at intermediate discharges (indicative of one-two turbine operations), from early to mid-September, early to mid-December 2004, early to mid-March and May, and most of June 2005; and
- operation essentially at full gate in late September, late October to mid-November 2004, , mid-December to early March 2005, mid-March to late April and from mid- to late May.

On a monthly basis, September, December and January exceeded the long-term median discharge values. Overall, the power station discharge pattern was less than usual from the 30th to the 80th percentiles, with a median value of 26 $m^3 s^{-1}$ compared with the long-term median of 132 $m^3 s^{-1}$.

Analysis of the duration and frequency of shut down events indicated that there were 30% more of these than in 2003-04, but with a similar modal range. No long-duration shut downs were recorded. In terms of operating events, the power station recorded more short- and long-duration start-ups than in 2003-04. The modal range was 16-20 hours, similar to previous years.

The compliance monitoring site (site 65) was established in January 2004 on the Gordon River, upstream of the Denison confluence. Its flow pattern and median monthly flow values were similar to those of the tailrace, with additional flow from upstream tributaries. The duration curve for this site was similar to that of the tailrace, but with increased flows between the 40th to 70th percentiles. At least some of this difference may be attributable to backwater from high Denison River flows.

The Gordon above Franklin (site 44) recorded a flow pattern which included the power station discharge plus some peak flow events produced by rainfall and tributary runoff. The data from this site showed that the flow pattern matched the power station tailrace discharge pattern closely from late October to late April. Natural high volume flow events originating in tributary streams were recorded in August 2004 and May 2005. The duration curve for site 44 showed the overall effect of the natural inflows.

The median discharge values at the tailrace, site 65 and site 44 for 2004-05 were 26, 141, and 164 $m^3 s^{-1}$, respectively, showing the downstream increase due to inflows from tributary streams.

3 Water Quality

Water quality parameters were measured in Lakes Gordon and Pedder and in the Gordon River downstream of the power station during 2004-05. The water quality monitoring sites are shown in Figure 2.1.

Figure 3.1. Map of the locations of water quality monitoring sites in Lakes Pedder and Gordon, and the Gordon River.

3.1 Field methods

In the lakes, chemical analysis was carried out on surface water samples. For each water sample, the following parameters were measured by laboratory analysis:

- total phosphorus and dissolved reactive phosphorus (DRP);
- nitrite, nitrate, total Kjeldahl nitrogen (TKN) and ammonia;
- chlorophyll-*a*;

- metals (Fe, Mn, Zn, Cd, Cu, Al, Co, Cr, Ni and Pb);
- sulphate;
- alkalinity; and
- dissolved organic carbon.

Additionally, depth profiles of basic physico-chemical parameters (water temperature, dissolved oxygen, conductivity, pH and turbidity) were taken at approximately 2 m vertical intervals at each of the sites in Lakes Gordon and Pedder.

3.1.1 Lake Gordon

During 2004-05, quarterly water quality monitoring was conducted in Lake Gordon at the power station intake, at Calder Reach and at Boyes Basin adjacent to the upper Gordon River inflow. Depth profiles of water temperature, dissolved oxygen, pH, and conductivity were taken to monitor the status of the water column at these sites. Surface water chlorophyll-*a*, water temperature, pH, conductivity, turbidity and dissolved oxygen concentration was also recorded at these locations and surface samples for laboratory measurement of nutrients and metals were collected.

3.1.2 Lake Pedder

Depth profiles were measured off Groombridge Point in Lake Pedder, which is the deepest part of the main body of the lake. Surface water samples measuring chlorophyll-*a*, water temperature, pH, conductivity, turbidity and dissolved oxygen were collected at Groombridge Point, Hermit Basin and Edgar Bay, while surface samples for laboratory measurement of nutrients and metals were collected from Groombridge Point.

3.1.3 Gordon River

Water quality monitoring was carried out at three sites on the Gordon River downstream from the Gordon Power Station. These were:

- Gordon Power Station tailrace (site 77);
- Gordon River at site 75 (G4 -Albert Rapids);
- Gordon River at site 62 (downstream of the Denison confluence).

Water temperature was logged at all three sites and dissolved oxygen was recorded at the tailrace site.

3.2 Lake Gordon water quality

Temporal changes in water temperature and pH for Boyes Basin, Calder Reach and the Intake site are shown in Figure 3.2. Temporal changes in dissolved oxygen for Boyes Basin, Calder Reach and the Intake site are shown in Figure 3.3. Depth profiles for each of the parameters varied with location, inflows and season.

3.2.1 Boyes Basin

Boyes Basin is the shallowest of the three monitoring sites, with depths ranging between 24 and 32 m during 2004-05. It is also located closest to the upper Gordon River which is one of the major inflows to the lake. In July, temperatures were generally isothermal ranging between 6.6°C at the surface to 4.8°C at 25 m. Temperatures increased in October and January. In October, temperatures ranged between 13°C at the surface to 7°C in bottom waters, while in January, stratification was more evident, with temperatures ranging between 19°C at the surface to 9°C in bottom waters. In April, temperature decreased at the surface and ranged between 11 and 15°C over the top 25 m.

The pH values remained relatively constant over depth, with values ranging between 5.7 and 6.7 for the July, October and April monitoring trips. In January, there was a slight decrease at depth to 5.2.

Dissolved oxygen levels were high in July and October ranging between 9-11 mg L^{-1} or 89-98% saturation. In January levels were high above 8 mg L^{-1} or 83% in the upper 20 m but decreased between 20 and 29 m as a result of thermal stratification. Dissolved oxygen approximated 4 mg L^{-1} or 22% at a depth of 25 m. Dissolved oxygen levels increased in April reaching 6 mg L^{-1} or 56% at depth and 8 mg L^{-1} or >78% saturation in the top 10 m of the water column.

Conductivity at Boyes Basin was low and ranged between 31-60.5 µS cm^{-1} over depth for each of the sampling days, while turbidity was low within the range of 2.51-4.15 NTU (Table 3.1). Chlorophyll-*a* was also low with a range of 0.4-5.18 µg L^{1} (Table 3.1). The maximum value of 5.18 µg L^{1} was recorded on 11 January 2005 and is slightly higher than is expected. However, a higher value was recorded in the previous year which suggests that some algal growth is occurring within the surface layer of Boyes Basin.

3.2.2 Calder Reach

The temperature profile for Calder Reach demonstrated the gradual heating of the water column from isothermal conditions in July to stratification in January and cooling in April (Figure 3.2). In January, surface and bottom water (42 m depth) temperatures approximated 21 and 9°C, respectively. In April, water temperatures approximated 14°C from the surface to 22 m before decreasing sharply to 10°C at 25 m depth. Below 25 m depth, temperature remained relatively constant throughout the year ranging from 7.6-10.5°C.

The pH profiles were similar to those measured at Boyes Basin ranging from 5.3-6.8 (Figure 3.2). The July and January pH profiles displayed a decrease with depth.

Dissolved oxygen levels were high in July and October ranging between 8.9-10.5 mg L^{-1} or 75-88% saturation (Figure 3.3). In January levels were high above 8.6 mg L^{-1} or 78% in the upper 20 m, but decreased between 20 and 42 m as a result of thermal stratification. In April, dissolved oxygen between the surface and 20 m depth was high at 9°C or 86% saturation. However, unlike at Boyes Basin, it decreased below 20 m, falling to 3.6 mg L^{-1} or 31% at 31 m depth.

Conductivity, turbidity and chlorophyll-*a* were all low ranging between 41.2-48.7 µS cm^{-1}, 2.37-5.12 NTU and 0.17-0.96 µg L^{-1}, respectively (Table 3.1).

3.2.3 Intake site

The temperature profiles at the power station intake displayed isothermal conditions in July, weak stratification in October and strong stratification in January with a deep surface mixed layer in April (Figure 3.2). In July temperatures approximated 8°C throughout the water column and dissolved oxygen was greater than 7.4 mg L^{-1} to a depth of 46 m (Figure 3.2, Figure 3.3). However, at 46 m an oxycline was evident with very low oxygen levels at a depth range of 54 and 74 m. The oxycline was also evident for other sampling days. In October, temperature ranged between 7.2-12°C, while dissolved oxygen ranged between 5.5-9.9 mg L^{-1}. In January, the temperature increased from 7°C at 80 m depth to 19°C at the surface. Dissolved oxygen displayed a constant decrease over depth ranging from 8.6 mg L^{-1} at the surface to 2.6 mg L^{-1} at 80 m. Similarly, to the other sampling sites, temperature ranged between 14°C at the surface to 7°C at 69 m, while dissolved oxygen was 8.8 mg L^{-1} at the surface, and an oxycline had developed at 20 m, with anoxia at 60-69 m.

The pH values at the intake displayed variability with time and depth (Figure 3.2). Values were higher at the surface ranging between 5.7-6.2 and 4.7-5.4 in the hypolimnion between July 2004-April 2005. Surface conductivity at the intake location was low and ranged between 36.6-45.0 µS cm-1 over depth for each of the sampling days, while turbidity was low within the range of 1.15-1.54 NTU (Table 3.1). Chlorophyll-a was also very low with a range of 0.17-1.37 µg L-1 and is typical for oligotrophic lakes (Table 3.1).

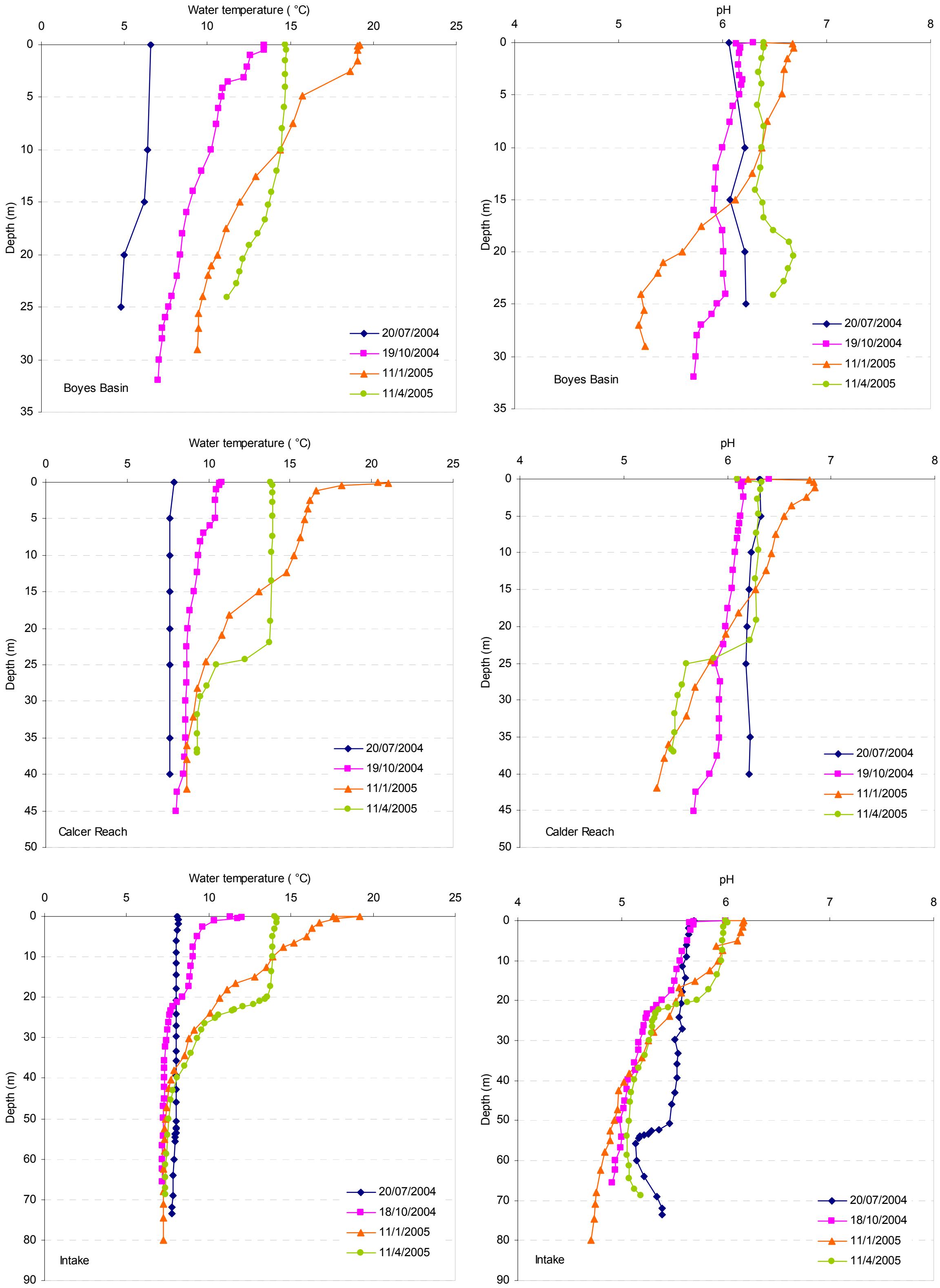


Figure 3.2. Depth profiles of water temperature (left) and pH (right) in Lake Gordon at Boyes Basin (top), Calder Reach (middle) and the power station intake (bottom) for 2004-05. Note: the intake depths were 26.9 m (20/07/04), 31.2 m (18 October 2004), 29.8 m (11 January 2005) and 24 m (11 April 2005).

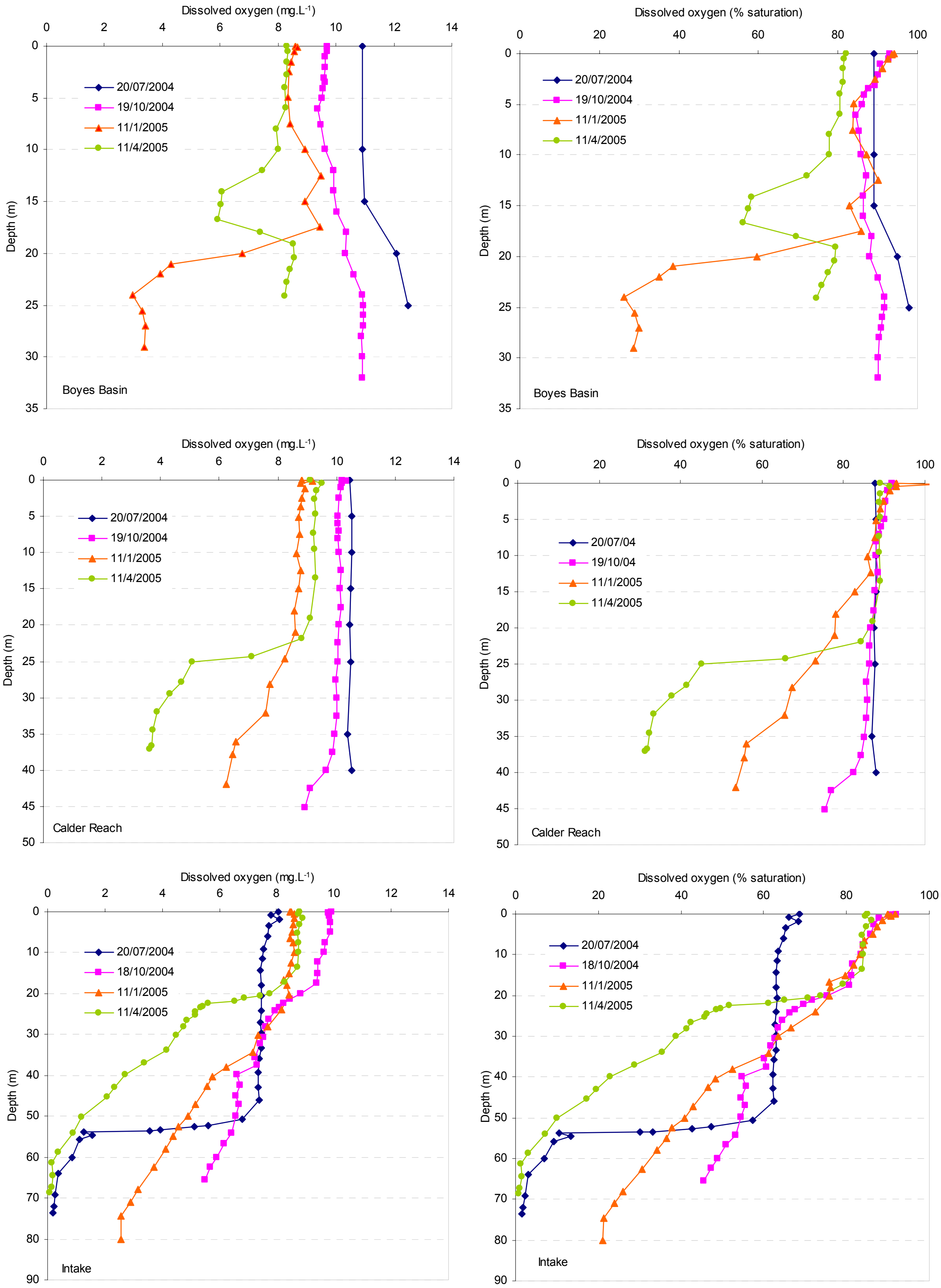


Figure 3.3. Depth profiles of dissolved oxygen concentration (left) and percent saturation (right) in Lake Gordon at Boyes Basin (top), Calder Reach (middle) and the power station intake (bottom) for 2004-05. Note the intake depths were 26.9 m (20 July 1004), 31.2 m (18 October 2004), 29.8 m (11 January 2005) and 24 m (11 April 2005).

3.2.4 Summary of surface water results

Surface water samples from Lake Gordon were analysed in the laboratory for the parameters listed in section 3.1 and results are presented in Table 3.1. The results are representative of Tasmanian fresh waters in the state's south western region with low nutrient and metal concentrations, relatively high dissolved organic carbon and slightly acidic pH values. Unlike in February 2004 no elevated chlorophyll-*a* levels were recorded at Boyes Basin. Alkalinity and sulphate concentrations were within the range reported last year.

Table 3.1. Value ranges of nutrients, metals, sulphate, alkalinity, dissolved organic carbon and chlorophyll-a taken from the surface of three monitoring sites in Lake Gordon during 2004-05.

Parameter	Boyes Basin	Calder Reach	Intake
Specific conductivity (μS cm^{-1})	31.0-60.5	41.2-48.7	36.6-45.0
Turbidity (NTU)	2.52-4.15	2.37-5.12	1.15–1.54
Chlorophyll-a (μg L^{-1})	0.4--5.18	0.17- 0.96	0.17-1.37
Dissolved organic carbon (mg L^{-1})	4.8-7.8	3.9-7.0	3.9-7.0
Total phosphorus (mg L^{-1})	<0.006	0.005-0.009	0.005-0.012
Dissolved reactive phosphorus (mg L^{-1})	0.002-0.003	<0.003	0.002-
Nitrite (mg L^{-1})	0.002-0.003	0.002-0.003	0.002-0.025
Nitrate (mg L^{-1})	0.043-0.047	0.062-0.065	0.028-0.095
Total Kjeldahl nitrogen (mg L^{-1})	0.196-0.280	0.171-0.289	0.161-0.228
Ammonia (mg L^{-1})	0.007-0.019	0.016-0.025	0.008-0.025
Iron (mg L^{-1})	0.488-0.518	0.465-0.673	0.439-1.120
Manganese (mg L^{-1})	0.006-0.008	0.006-0.008	0.006-0.067
Zinc (mg L^{-1})	0.001-0.004	0.001-0.006	0.001-0.004
Cadmium (mg L^{-1})	<0.001	<0.001	<0.001
Copper (mg L^{-1})	0.001-0.006	0.001-0.007	0.001-0.007
Aluminium (mg L^{-1})	0.146-0.235	0.157-0.261	0.137-0.273
Cobalt (mg L^{-1})	<0.001	<0.001	<0.001
Chromium (mg L^{-1})	<0.001	<0.001	0.001-0.002
Nickel (mg L^{-1})	<0.001	<0.001	<0.001
Lead (mg L^{-1})	<0.005	<0.005	<0.005
Sulphate (mg L^{-1})	1-1.30	1.2-1.4	1.1-1.80
Alkalinity (mg L^{-1})	5-14	6-7	5-11

3.3 Lake Pedder water quality

Lake Pedder is relatively shallow (averaging 15 m depth) and well mixed. Depth profiles of temperature displayed isothermal conditions in July, October and April with some surface heating in January (Figure 3.4). The temperature profiles also demonstrated a gradual heating of the water body from winter at 6°C to 14-15°C in summer. The resulting effect of the well mixed lake was that water quality parameters did not change with depth which is consistent with the 2003-04 monitoring results. Water samples from the surface were analysed for a range of parameters as outlined in section 3.1. As in previous years water quality was high in Lake Pedder. Conductivity, turbidity, chlorophyll-*a*, nutrient and metal concentrations were all low, while dissolved oxygen was high in surface waters and pH was slightly acidic (Table 3.2). Dissolved organic carbon concentrations (Table 3.3) were similar to those measured in Lake Gordon.

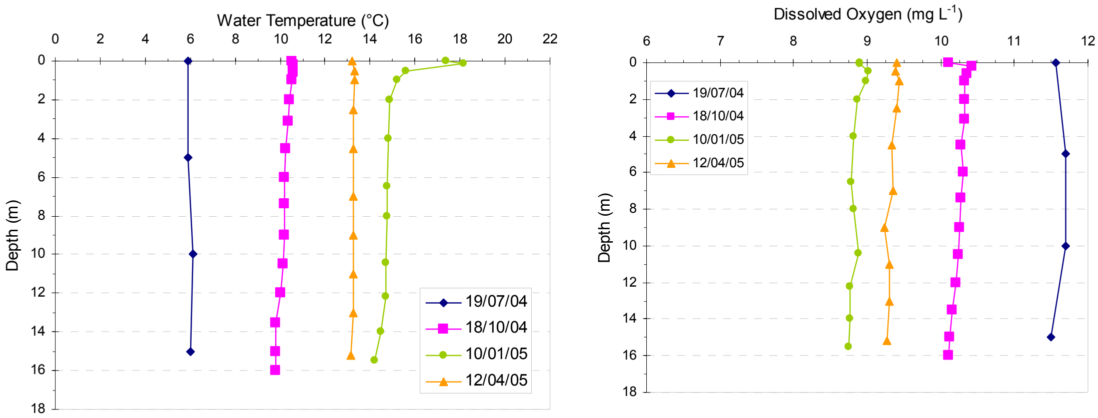


Figure 3.4. Depth profiles of water temperature (left) and dissolved oxygen concentration (right) at Groombridge Point, Lake Pedder for 2004-05.

Table 3.2. Surface water quality parameter ranges measured at the three monitoring sites in Lake Pedder during 2004-05.

Parameter	**Edgar Bay (surface)**	**Hermit Basin (surface)**	**Groombridge Point (surface)**	**Groombridge Point (15 m)**
Chlorophyll-a (µg L-1)	0.55 - 1.12	0.48 - 2.09	0.59 - 1.08	-
Dissolved oxygen (mg L-1)	9.20 - 11.51	8.80 - 11.41	8.90 - 11.57	8.75 - 11.50
Dissolved oxygen (% saturation)	89 - 95	98 - 94	93.0 - 93.6	89.1 - 92.5
pH	5.94 - 6.34	5.38 - 5.83	5.90 - 6.17	5.97 - 6.4
Turbidity (NTU)	0.88 - 1.92	0.67 - 1.00	0.41 - 2.20	0.84 - 2.32
Conductivity (µS cm-1)	43.5 - 47.4	39.8 - 45.1	43.0 - 46.0	40.2 - 46.0
Water temperature (°C)	6 - 16.5	6.4 - 17.8	5.9 - 18.1	6.0 - 14.2

Table 3.3. Value ranges of nutrients, metals, sulphate, alkalinity, and dissolved organic carbon at Groombridge Point, Lake Pedder during 2004-05.

Parameter	Range (mg L^{-1})
Total phosphorus	0.005 - 0.008
Dissolved reactive phosphorus	0.002 - 0.003
Nitrite	<0.003
Nitrate	0.052 - 0.055
Total Kjeldahl nitrogen	0.171 - 0.198
ammonia	0.013 - 0.019
Iron	0.208 - 0.245
Manganese	<0.005
Zinc	0.001 - 0.004
Cadmium	<0.001
Copper	0.001 - 0.006
Aluminium	0.097 - 0.127
Cobalt	<0.001
Chromium	<0.001
Nickel	<0.001
Lead	<0.005
Sulphate	1.30 - 1.40
alkalinity	4 - 6
Dissolved organic carbon	3.80 - 6.20

3.4 Water quality in the Gordon River

Gordon River water temperatures were measured at the tailrace (site 77), site 75 (G4) and site 62 (Gordon u/s Denison confluence), while dissolved oxygen was measured at the tailrace.

The regulated discharge regime tends to govern water temperature and dissolved oxygen in the middle Gordon River downstream of the power station. Discharged water is sourced from the Lake Gordon via a deep intake, which ensures that the temperature remains relatively constant (Figure 3.2). The dissolved oxygen concentration of discharged water is influenced by lake level, degree of thermal stratification and power station operating conditions (i.e. number of turbines) (Figure 3.3).

3.4.1 Missing or unavailable data

Water temperature and dissolved oxygen data are missing from the the tailrace dataset for short periods during the 2004-05, as a result of equipment failures. The break downs were generally short, at less than a week.

The second issue with the tailrace data set is that high temperature ‘spikes’ of greater than 20°C were evident between November 2004 and January 2005. These spikes are attributed to the heating of holding chambers during the sampling process. Water is drawn from the tailrace to a chamber, temperature measured and then water is released. During summer, the holding chamber heats up causing an erroneous increase in water temperature. Consequently, the high water temperatures recorded at the tailrace were not consistent with the temperature of the water discharged. Furthermore, large differences in water temperature are evident between the tailrace and site 75 between October 2004 and February 2005. This differentiation is also likely attributable to chamber heating as part of the sampling system at the tailrace.

Data for site 75 were available only until 2 April 2005 (the latest downloading trip). Data were also unavailable at site 75 for the period of 19 April - 9 October 2004, due to battery failure.

3.4.2 Water temperature

Water temperature was monitored at the tailrace (site 77), site 75 (G4) and site 62 (Figure 3.5). Data is presented for the tailrace for the period of March to October 2004 only due to sampling problems identified above. Site 77 is telemetered, while sites 75 and 62 require manual downloads. As a consequence no data are available post April 2005 until the next maintenance trip. For consistency, data are presented from March 2004 to March 2005 for sites 75 and 62. While this is outside the usual July-June reporting period, it continues the analysis timeline from the 2003-04 report for these sites. Site 77 is 2 km downstream of the tailrace, while site 62 is a further 10 km downstream below the Denison and Maxwell river confluences.

Tailrace water temperature followed a seasonal pattern with temperatures ranging from approximately 13 °C in March 2004 to 7-8°C in August 2004 before increasing to 9-10°C in October (Figure 3.5). A similar seasonal decrease and increase is evident at the downstream sites of 75 and 62. Higher temperatures were recorded at site 62 compared to site 75 for the period of December 2004 to March 2005. Temperature at site 62, ranged from approximately 12°C in March 2004 to 8°C in August 2004 to 13°C in March 2005.

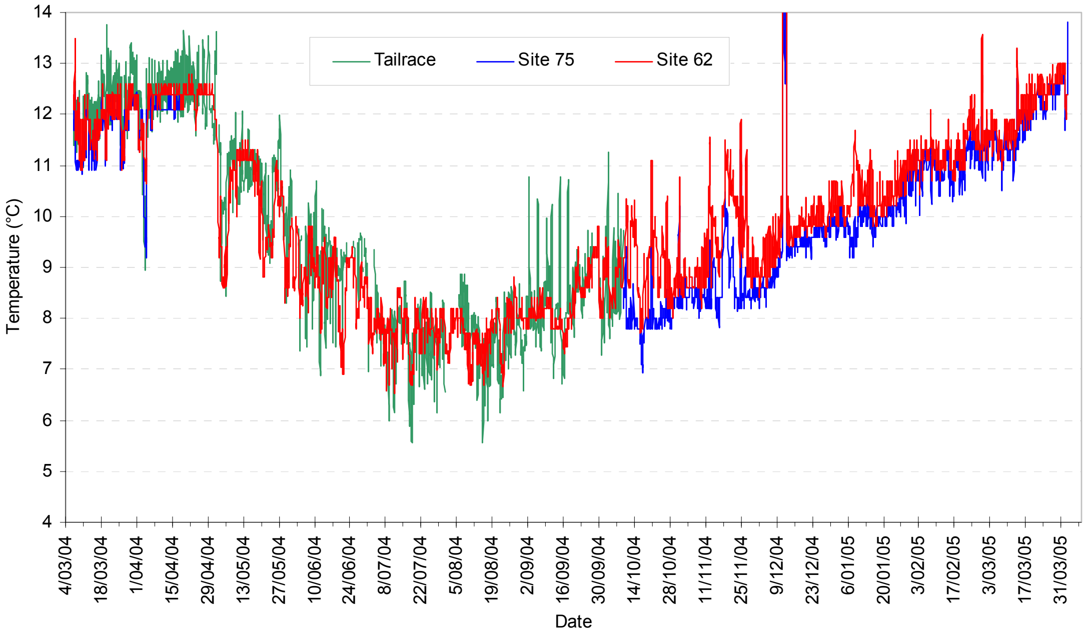


Figure 3.5. Water temperature data recorded for sites 77 (tailrace), 75 (2 km downstream of the tailrace) and 62 (15 km downstream of the tailrace) from July 2004 to April 2005. Note data from site 77 is telemetred while sites 75 and 62 are

downloaded manually from the datalogger and consequently recent data is not available until the next maintenance trip. Data from site 77 is only presented for the period of 7 March -9 October 2004.

To assess the influence of power station discharge on downstream temperatures, discharge from the tailrace (site 77) was plotted against temperature at sites 75 and 62 (Figure 3.6). Three scenarios were plotted representing months when there was intermittent discharge (August 2004, Figure 3.6a), extended period of no discharge (early October 2004, Figure 3.6b) and high discharge (January 2005, Figure 3.6c). Note that temperature data from site 77 were used in August 2004 as site 75 data were not available. Discharge was intermittent in August ranging from no discharge to 155 m^3 s-^{1}. The temperature recorded at the tailrace (site 77) tended to vary between 5.6-9.8°C while at site 62, the variation was less pronounced ranging between 6.8-8.3°C. The water temperatures at both sites also tended to stay within 1°C of each other during August.

During October 2004 there was an initial period of power station shutdown followed by high discharge conditions of >150 m^3 s^{-1}. During the period of no discharge or <40 m^3 s^{-1}, temperature was higher at site 62 compared to 75, with an approximately 1.5°C difference. On 18 October and towards the end of the month, discharge increased to >100 m^3 s^{-1} resulting in similar temperatures at sites 75 and 62.

Similar temperatures at sites 75 and 62 were recorded in January 2005 during periods of high discharge. Water temperature varied at both sites 75 and 62 between 10-11°C. A period of no discharge between 7-9 January resulted in an increase in temperature at site 62 by approximately 2°C compared to site 75.

The effects of regulated water temperature and discharge regimes on water temperatures at sites downstream of he power station is discussed in more detail in the Basslink Baseline Report, which takes advantage of the longer period of record available for such analyses.

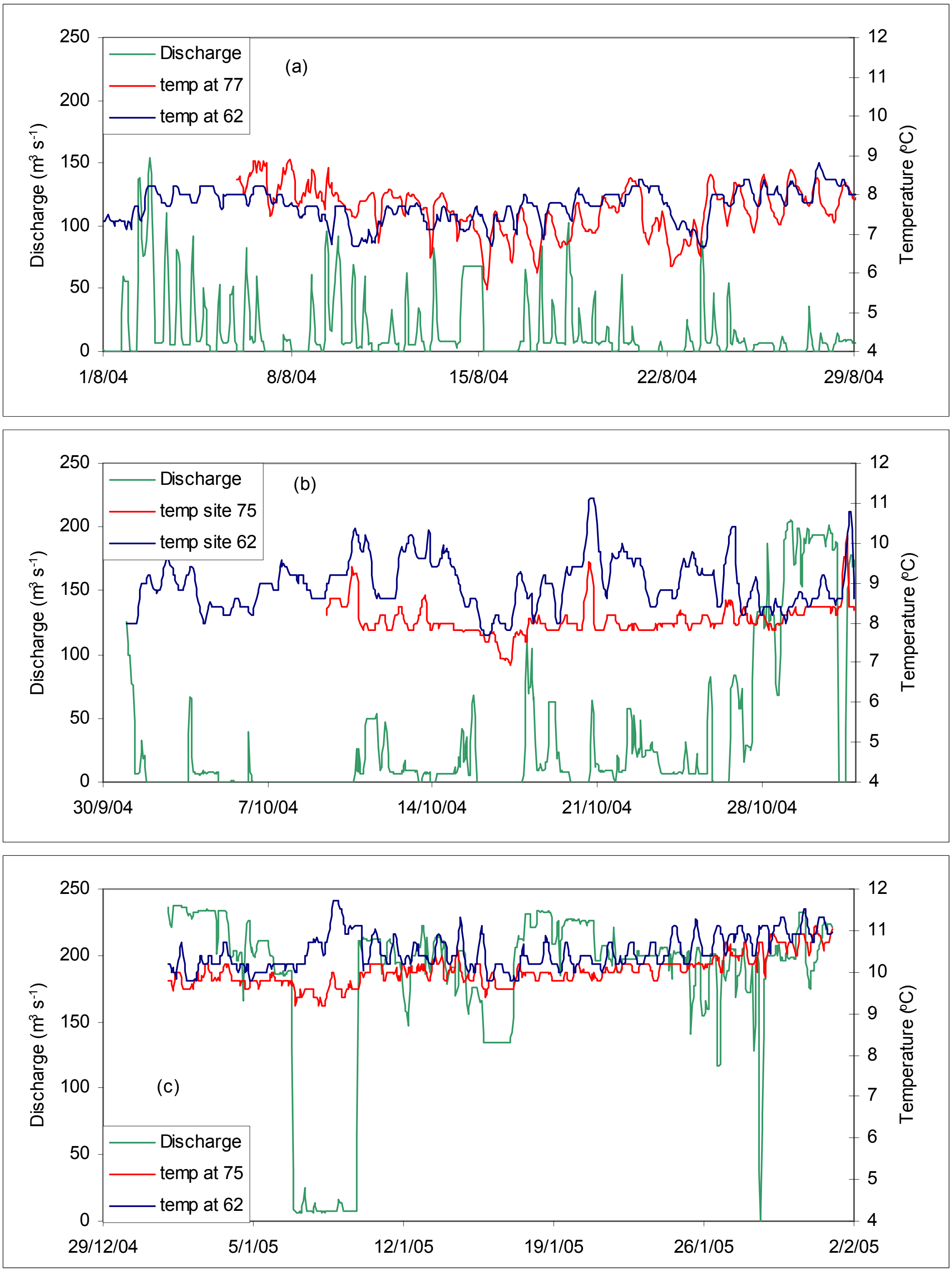


Figure 3.6 Water temperatures at sites 77 (tailrace). 75 (2 km downstream) and 62 (15 km downstream) and corresponding power station discharge for (a) August 2004, (b) October 2004 and (c) January 2005.

3.4.3 Dissolved oxygen

Dissolved oxygen levels at the power station tailrace (site 77) for the period of July 2004 to June 2005 are shown in Figure 3.7. There were short periods of missing data for 31 July-6 August 2004, 27-30 September 2004, 16-21 December 2004 and 5 January 2005.

Dissolved oxygen concentrations were generally medium-high with a median of 7.7 mg L^{-1} and a range between 5.8 mg L^{-1} on 8 March 2005 to 13.2 mg L^{-1} on 18 July 2004. Between July and December 2004, concentrations were above 8 mg L^{-1} and tended to vary around 10 mg L^{-1}. The power station was run both intermittently and under high discharge conditions in September and October 2004 (Figure 2.3). After December, concentrations tended to range between 6-8 mg L^{-1} until April 2005. In April and May dissolved oxygen levels increased slightly and remained near 8 mg L^{-1}. Spot dissolved oxygen values recorded at the intake (from depth profiles) are also included in Figure 3.7. The lake dissolved oxygen concentrations were lower than those measured in the tail race by approximately 2.5 mg L^{-1} on 20 July and 18 October 2004, were about 1.5 mg L^{-1} lowerer on 11 April 2005, while they were approximately the same on the 11 January 2005.

The data for 2004-05 did not indicate any unusual conditions with respect to dissolved oxygen. Dissolved oxygen concentrations fell only slightly below 6 mg L^{-1} on a few single days and also between late February and early March (Figure 3.7).

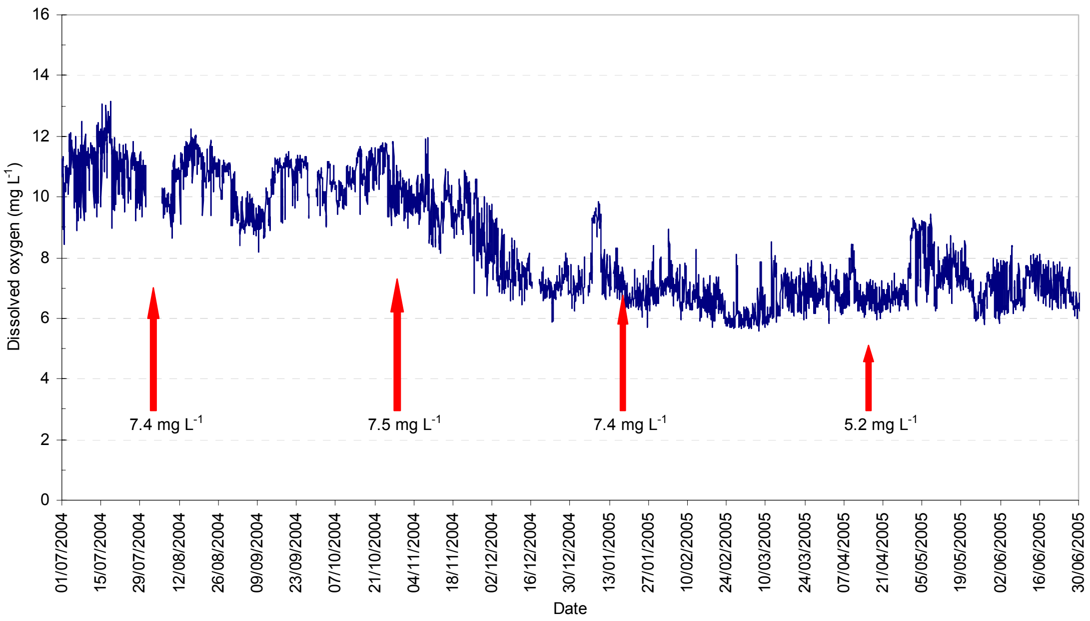


Figure 3.7. Dissolved oxygen values recorded at the power station tailrace from July 2004 to June 2005.

3.5 Conclusion

Water quality surveys were undertaken on Lake Gordon and Lake Pedder in July and October 2004 and January and April 2005. The physico-chemical conditions for both lakes were considered normal for lakes in the region with seasonal affects. Water quality was high in both lakes and was characterised by low nutrient concentrations, low turbidity levels and low chlorophyll-*a* levels. Metal concentrations were also low or at near detectable levels.

The thermal structure of Lakes Gordon and Pedder were also similar to previous years. Parameter values recorded in the depth profiles varied with location and between monitoring trips. Dissolved oxygen levels generally remained high and above 3 mg L^{-1} at Boyes Basin and Calder Reach. Anoxia was evident in July and April at the intake site, but this was below the level of the intake structure. Lake Pedder remained evenly mixed during 2004-05. No stratification in any of the water quality parameters was evident.

In the Gordon River, water temperature was recorded at three sites (tailrace-77, 75 and 62) and dissolved oxygen at the tailrace. Water temperatures displayed a broad seasonal pattern related to the thermal pattern of Lake Gordon. Periods of low discharge resulted in approximately 2°C temperature increase at site 62 compared to 75. Conversely, high discharge conditions resulted in similar temperature values at sites 75 and 62. Dissolved oxygen concentrations within the tailrace were generally at medium to high concentrations and there were few periods when levels fell below 6 mg L^{-1}. The high dissolved oxygen concentrations of 10-12 mg L^{-1} were associated with a high power station output.

4 Fluvial Geomorphology

This section summarises the Basslink fluvial geomorphology monitoring results for October 2004 – March 2005. The Basslink Baseline Report (BBR) will summarise the findings from the past four years of fluvial geomorphology monitoring. The BBR focuses on identifying rates and trends over the 4-year period and should be consulted for this integrated data analysis. This section summarises field observations and monitoring results from the October 2004 and April 2005 monitoring trips, but does not integrate this information with previous findings.

The monitoring program aims to document fluvial geomorphological processes and changes in the middle Gordon River between the power station tailrace and the confluence with the Franklin River (defined as the middle Gordon River), and relate these changes to power station operations or other factors wherever possible. The information will be used as a baseline against which post-Basslink monitoring results will be compared.

Details of the monitoring approach, monitoring program and its relationship with the initial Basslink geomorphology investigations were presented in the 2001-02 Gordon River Basslink Monitoirng Report (Hydro Tasmania 2002) and should be consulted for background material pertaining to the monitoring program. Descriptions of the zones, bank types and processes operating in the middle Gordon River are contained in the initial Basslink IIAS report (Koehnken *et al.,* 2001).

4.1 Methodology

Geomorphology monitoring included the measurement of 200 erosion pins and 25 scour chains located at 48 monitoring sites in the middle Gordon River on a 6-monthly basis, and photo-monitoring of an additional 54 sites on an annual basis in March each year. Site locations and site descriptions are contained in the 2001-02 Gordon River Basslink Monitoirng Report (Hydro Tasmania 2002). Figure 4.1 shows the location of the geomorphology monitoring zones in the middle Gordon River.

4.1.1 Monitoring in March 2004-April 2005

Monitoring was undertaken on 9-10 October 2004 and 2, 3, 9 and 10 April 2005. The autumn monitoring was completed over two weekends due to inclement weather during the first scheduled weekend. The monitoring was completed in April rather than March, as has been the case for the past 3 years due to constraints on shutting down the Gordon Power Station. An additional fieldtrip was completed on 11 December 2004 for the purpose of establishing additional erosion pins in zones 1-3. Additional erosion pins were added to zones 4 and 5 during April 2005.

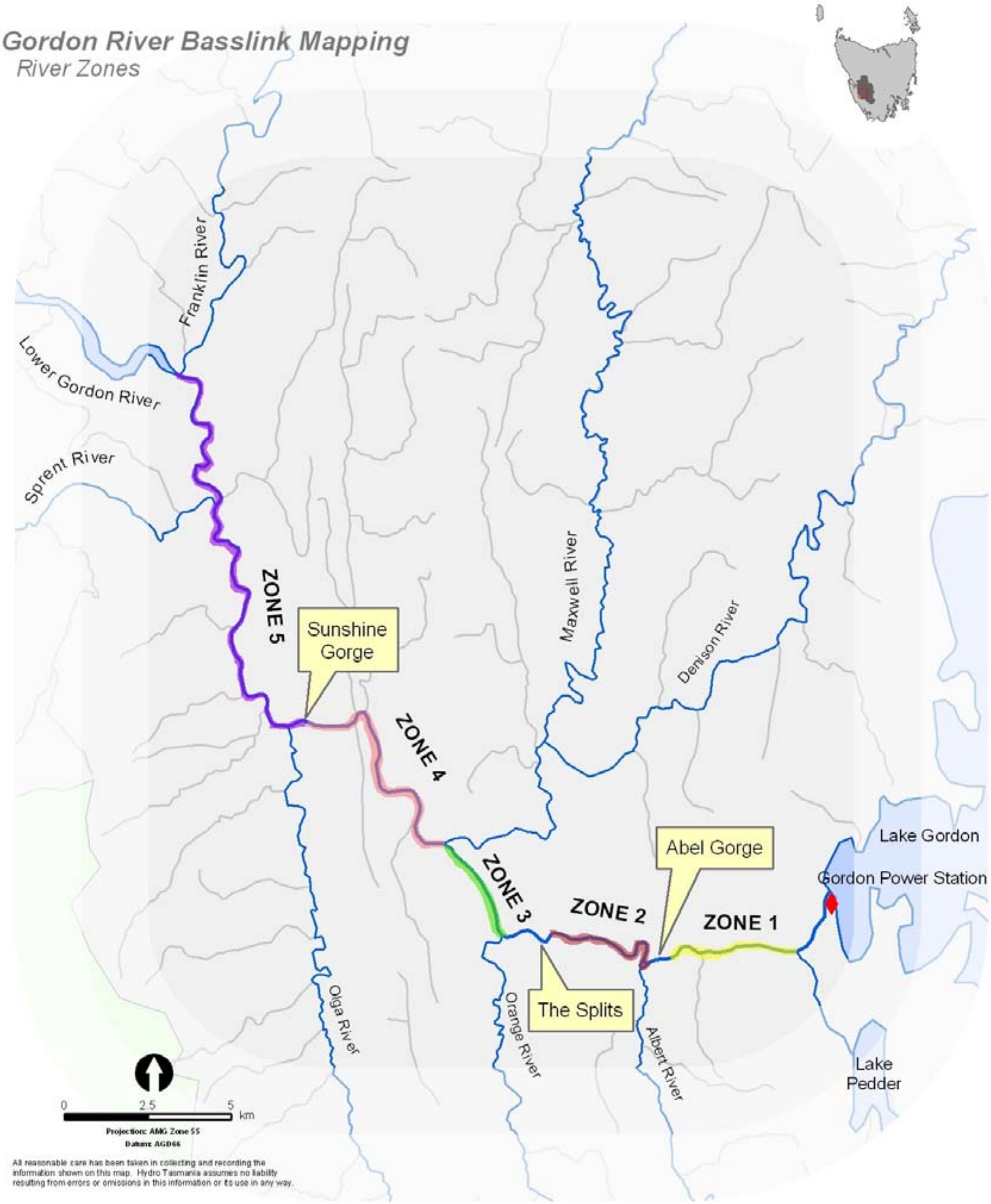


Figure 4.1. Map of middle the Gordon River showing the location of the five geomorpgology monitoring zones.

4.1.2 Additions to monitoring program

Between March 2003 and March 2004, the monitoring program was augmented to include the measurement of bank angles at a range of sites, the profiling of banks using simple hand-levelling techniques, and the installation of additional pins. The reason for these additions to the monitoring program was to augment the available pre-Basslink information based on what a detailed analysis of the pre-Basslink monitoring results were showing.

Bank profiles were measured so that the position of erosion pins relative to turbine operating levels could be estimated, and future changes to bank profiles assessed (an example is shown in Figure 4.2). The profiles were obtained using a clinometer and measuring stick, and measuring distances and angles up the bank relative to low water level. The location of erosion pins was noted during the profiling, as were bank attributes such as the initiation of vegetation and/or evidence of high water level. The profiles are contained in appendix 1 (Fluvial geomorphology site descriptions). When viewing the profiles it is important to remember that water levels were quite high during the measurements, and the 1-turbine power station operating level was close to water level at the time of measurement. Profiles will be re-measured during the post-Basslink monitoring period, with the exact timing to be determined based on post-Basslink field observations and erosion pin results.

As shown in Figure 4.2, some alluvial banks in the middle Gordon show distinct break points which are associated with the operating levels of the power station (1, 2, or 3 turbines). The characteristic profile includes a horizontal break in the slope at or slightly below the 1, 2, or 3-turbine operating level of the power station, separated by a slope of 30-40 degrees.

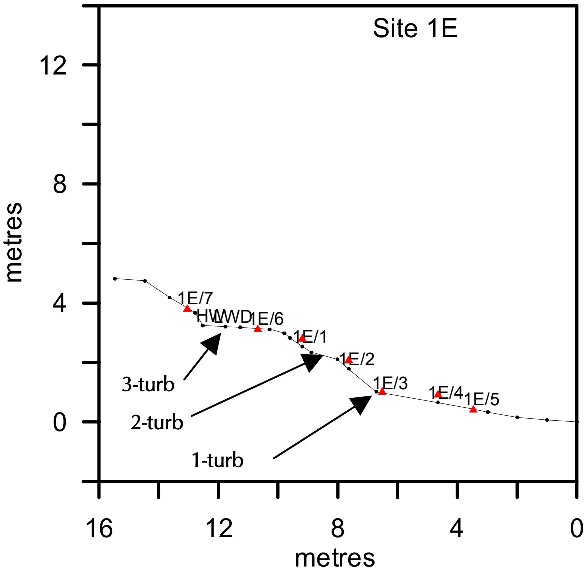


Figure 4.2. Bank profile in zone 1 of Gordon River reflecting turbine operating patterns. Labels indicate placement of erosion pins on bank, and HW, and LWD denote the High Water level and placement of Large Woody Debris respectively. Arrows indicate approximate water level associated with 1-, 2- and 3-turbine power station operation.

To assist in detecting and understanding post Basslink changes, the measurement of bank slopes separating the turbine levels has been initiated at a number of sites. This information will allow erosion pin results to be interpreted with respect to large scale bank re-adjustment.

Table 4.1 contains a summary of changes to erosion pin sites during between March 2003 and April 2004.

Table 4.1. Summary of erosion pin changes between March 2004 and April 2005

Site	Change(s) to site	Reason
1B	1B/4 & 1B/5 re-established	Pins dislodged through removal of 'root mat drape' overlying bedrock
1E	Pins1E/6 & 1E/7 established	To increase number of erosion pins in 2-3 turbine level
1E	Bank angles at Pins 1E/2 &1E/ 7 measured	
2D	Pin2D/5 established	To increase number of erosion pins in 2-3 turbine level
2D	Bank angles at Pin 2D/5 measured	
2G	Pins 2G/7 & 2G/8 established	To increase number of erosion pins in 2-3 turbine level
2G	Bank angles at pins 2G/7 and 2G/8 measured	
2L	Pins 2L/5 & 2L/6 established	To increase number of erosion pins in 2-3 turbine level
2L	Bank angles at pins 2L/5 and 2L/6 measured	
3A	Pins 3A/5 & 3A/6 established	To increase number of erosion pins in 2-3 turbine level
3A	Pin 3A/55 established	Marks level of 55 $m^3 s^{-1}$ environmental flow on bank
3A	Bank slope measurement at pins 3A/5 &3A/6	
3C	Pin 3C/55 established	Marks level of 55 $m^3 s^{-1}$ environmental flow on bank
3D	Pin 3D/4 established	To increase number of erosion pins in 2-3 turbine level (probably above 3-turbine level under some flow conditions)
3D	Pin 3D/55 established	Marks level of 55 $m^3 s^{-1}$ environmental flow on bank
3D	Bank slope at pin 3D/2 measured	
3Eb	Pin 3Ea/6 established	Monitor slope separating 1-2 turbine levels
3Eb	Pin 3Ea/55 established	Marks level of 55 $m^3 s^{-1}$ environmental flow on bank
4A	Pin 4A/4 established	To increase number of erosion pins in 2-3 turbine level
4A	Bank slope at 4A/2 measured	
4B	Pin 4B/4 established	To increase number of erosion pins in 2-3 turbine level
4B	Bank slope at 4B/4 measured	
4D	Pins 4D/4 & 4D/5 established	To increase number of erosion pins in 2-3 turbine level
4H	Bank slope at 4H/1 and 4H/3 measured	
5A	5A/1 & 5A/2 re-established	Old 5A/1 & 5A/2 lost under bank collapse Oct 2004; new pins installed April 2005
5B	Pins 5B/5 & 5B/6 established	To increase number of erosion pins in 1-2 turbine level
5C	Pin 5C/4 established	To increase number of erosion pins in 2-3 turbine level
5I	Pins 5I/5 & 5I/6 established	To increase number of erosion pins in 1-2 and 2-3 turbine level
5J	Pins 5J5 & 5J/6 established	To increase number of erosion pins in 1-2 and 2-3 turbine level
5k	New 5K/1 established	Old 5K/1 (probably) buried

4.2 Overview of hydrology, March 2003 – March 2004

Hourly discharge from the power station is shown in Figure 4.3 for the period 1 January 2004 – 1 May 2005. The graph shows that, consistent with typical power station operation, high flow generally occurred during the drier months, with lower discharge during the winter months. This pattern is similar to the previous pre-Basslink monitoring years, however the duration of two and three turbine flow is lower than in previous years, as shown in the flow duration curves in Figure 4.4. In the 2004-2005 monitoring year, power station discharge exceeded 150 $m^3 s^{-1}$ and 200 $m^3 s^{-1}$ only ~30% and 10% of the time, respectively. In previous monitoring years, these flows were exceeded up to 60% (150 m^3 s^{-1}) and 40% (200 m^3 s^{-1}) of the time. The duration of power station shut down or 'spinning reserve' (<10 m^3 s^{-1}) during March 2004-April 2005 was similar to previous years, at about 35%.

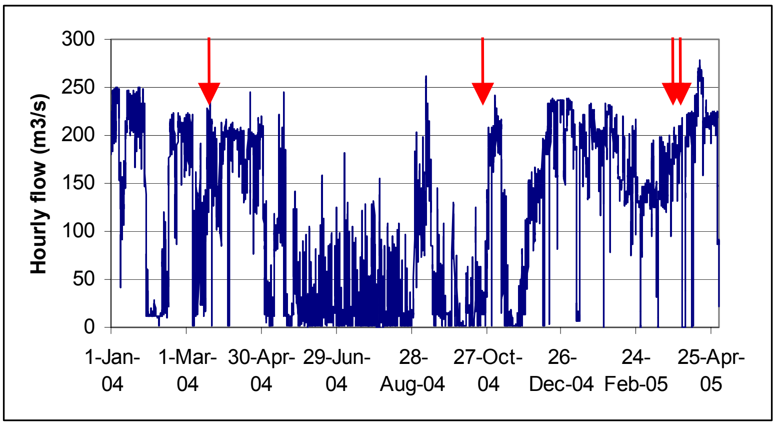


Figure 4.3 Power station discharge, 1 January 2004– 1 May 2005. Arrows indicate sampling dates.

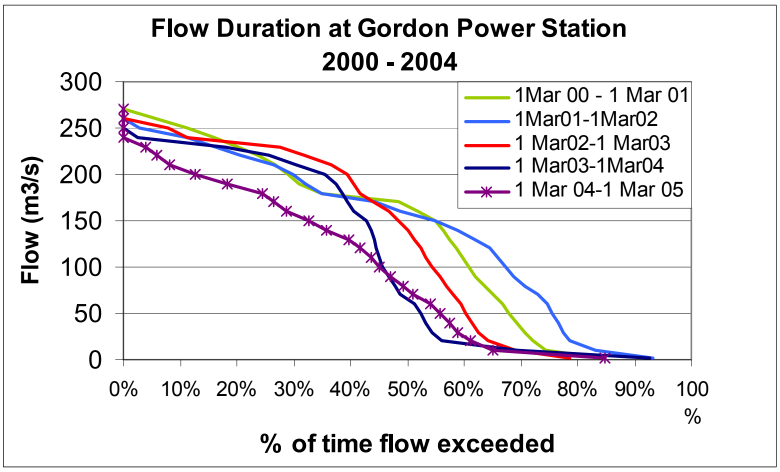


Figure 4.4. Flow duration curves comparing March 2004-05 with previous pre-Basslink monitoring years.

Figure 4.5 shows the hourly time series for flow at the Gordon above Franklin monitoring site, which indicates catchment inflows downstream of the power station, superimposed on the power station discharge record. Between March 2004 and March 2004 there were some large flow events in the Gordon below the Denison, including one flood in early July which exceeded 1000 m^3 s^{-1}. These events coincided with low or no power station usage.

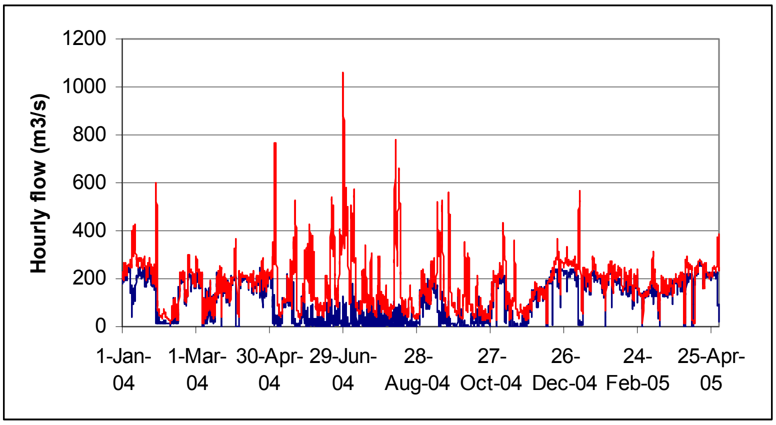


Figure 4.5. Gordon below Franklin hourly flow record superimposed on power station flow.

4.3 Water level changes in zone 3

The installation of the Basslink 'compliance' site (site 65) upstream of the Denison (in zone 3) has provided an opportunity to better understand water level changes in this reach of the river. Water level is recorded at the compliance site, and also upstream of the Splits, at site 72 (5G) (~500 m upstream of piezometer site). Figure 4.6 compares the river levels, both of which are based on arbitrary reference levels (ie, not relative to each other), and Figure 4.7 plots the levels against each other for a dry summer period, and a wet winter period. The plots show that most of the time, flow at the compliance site is controlled by discharge from the Gordon Power Station, leading to a strong correlation between levels at the two sites (blue circles). During large storm events, such as those which occurred over June 2004-July 2005, water level at the compliance site was several metres above that predicted by the water level at site G5. Because the catchment area between these two sites is only ~30 km^2, it is highly improbable that the large increase in water level is due to the entrance of the Orange River, and highly probable that the increase is due to a backwater effect from the Denison River. This is consistent with the survey results which showed that the mouth of the Denison at low flow is <1 m lower than the water level at the compliance site at low flow.

This backwater effect has implications for the fluvial geomorphology of zone 3, in that the banks are inundated during periods of high discharge from the Denison River, even if the power station is not discharging. The elevated water levels would saturate banks under very low velocity flow conditions, and promote deposition of material transported by the Denison, or the inflow from the Orange River. This is the likely processes behind large depositional events which periodically occur at site 3A, which is generally dominated by erosion.

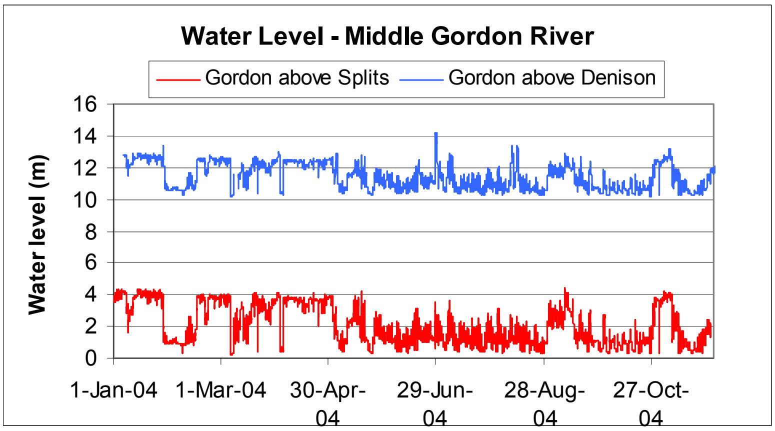


Figure 4.6. Comparison of water levels at site 72 (Gordon above Splits) and Site 65 (Gordon above Denison).

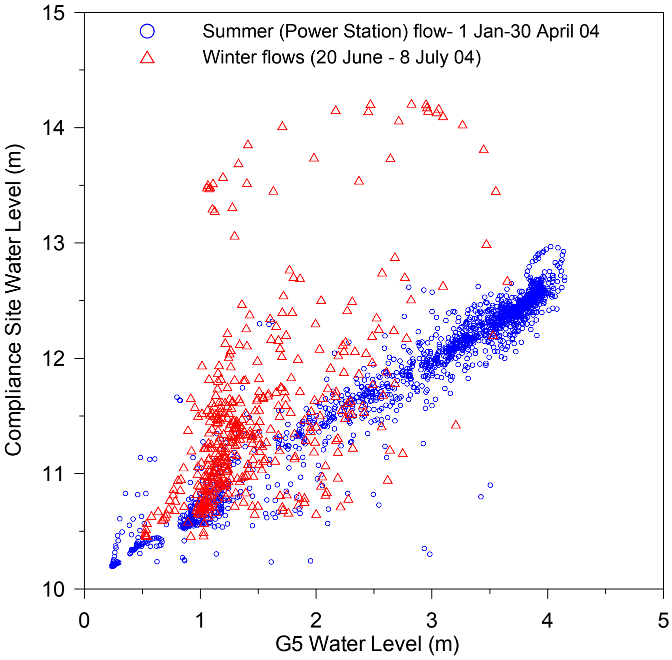


Figure 4.7. Comparison of water level at site 72 (G5) in zone 2 and the compliance site (Site 65, zone 3)) for summer and winter flows.

4.4 Monitoring results

4.4.1 Field observations October 2004

Monitoring in October 2004 coincided with relatively high flow in the catchment. Although the power station was shut down, flow at the Gordon above Denison site (Site 65) was 20 m^3 s^{-1} and inflows from the Denison and other tributaries were considerable, resulting in flows of 220 m^3 s^{-1} at the Gordon above Franklin site (site 44). The high flows were the result of a storm event which peaked at the Gordon above Franklin site on 8 October 2004, with a flow of 305 $m^3 s^{-1}$. These high flows resulted in the inundation of many erosion pins, especially those situated on bank toes. Due to the water depths, some pins were not located, and others were difficult to measure due to the depth of water (up to 1 m) and the waterlogged and very soft nature of the sediment surrounding the base of the pin.

Field observations in October 2004 were consistent with both the high natural inflow events occurring before and during monitoring and the low previous usage of the power station. In zones 1 and 2, there were abundant algae on rocks in the channel, and grasses and mosses were present at many sites below the power station controlled water levels. This is consistent with previous October monitoring which coincided with prolonged power station shut downs, and is likely to be related to light penetration onto the lower banks during the extended period of low or no power station discharge.

In general, the banks were not saturated at or above the 2-3 turbine power station operating level, although some of the toes were saturated due to the recent high flow event (or still underwater). This is consistent with the lack of 2 and 3 turbine power station operation immediately prior to monitoring.

In zone 2, a veneer or recently deposited sand was present on the lower banks. With distance downstream, the abundance and vertical distribution of the sand deposits increased, reflecting the increasing water levels and sediment input. The sand deposition in zone 5 appeared to be considerably greater than in the other zones, and recent flood debris was present in trees up to 5 m higher than the power station-controlled water levels. It is probable that this deposition was associated with the very large flood event which occurred at the end of June 2004. Mud was also present in zones 3-5 below the water level on lower bank toes.

Between March 2004 and October 2004 there was a bank collapse at site 5A which obscured two erosion pins located in a bank cavity. The collapse appeared to be due to the failure of the root mat on the surface of the bank. A photo of the scarp created by this collapse is shown in Photo 4.1.

Similar to all sites in zone 5, sand deposition was present at the site including at, and upslope of, the scarp. It is unknown whether the bank collapse occurred before, during or after the June 2004 flood event.

Photo 4.1. Scarp created by bank collapse at site site 5A.

4.4.2 Field observation April 2005

Monitoring in April 2005 was completed over 2 weekends (2-3 April 2005, 9 April 2005) due to poor weather preventing helicopter access on the Sunday of the first weekend. Zones 1, 2, 3 and 5 were completed during the first weekend, with zone 2 completed the second weekend. Water levels were low during both weekends, with ~3 $m^3 s^{-1}$ at the Gordon above Denison site, and ~25 $m^3 s^{-1}$ at the Gordon above Franklin site.

Between the October 2004 monitoring and April 2005 monitoring, flow in the river was dominated by power station releases, consisting of predominantly 3-turbine releases (180-200 $m^3 s^{-1}$). The largest storm event between the two monitoring dates occurred in early January 2005, with peak flows of 540 $m^3 s^{-1}$ at the Gordon above Franklin site.

Field observations of the banks were consistent with prolonged 3-turbine power station operation; water was draining from the 1-2 turbine level of the banks, and there were recently deposited flows further up the banks. There was little or no evidence of recent deposition of muds or organic material on bank toes or bank faces in any of the zones.

On the second day of the first monitoring weekend (3 April 2004), heavy rain fell as the lower portion of zone 1 was monitored. The rainfall resulted in the re-activation of gullies in the banks in the 0-2 turbine zone as preferential flow paths. Sediment-laden drainage was observed flowing down the banks in these channels, as shown in Photo 4.2. Erosion due to sheetwash over the banks was also observed.

Photo 4.2. Bank erosion in zone 1 during high rainfall.

4.4.3 Zone 2 piezometer results

Piezometer results for the period 1 March 2004 to 6 April 2005 are presented in Figure 4.8, and bank water surface slopes as determined by the difference in water level height between Probe 1 and Probe 3 (13.3 m inland) are shown in Figure 4.9. The black lines in the graph show periods when there would have been a high risk of seepage erosion, due to high in-bank water surface slopes, and elevated water levels in the bank (>2.75 m).

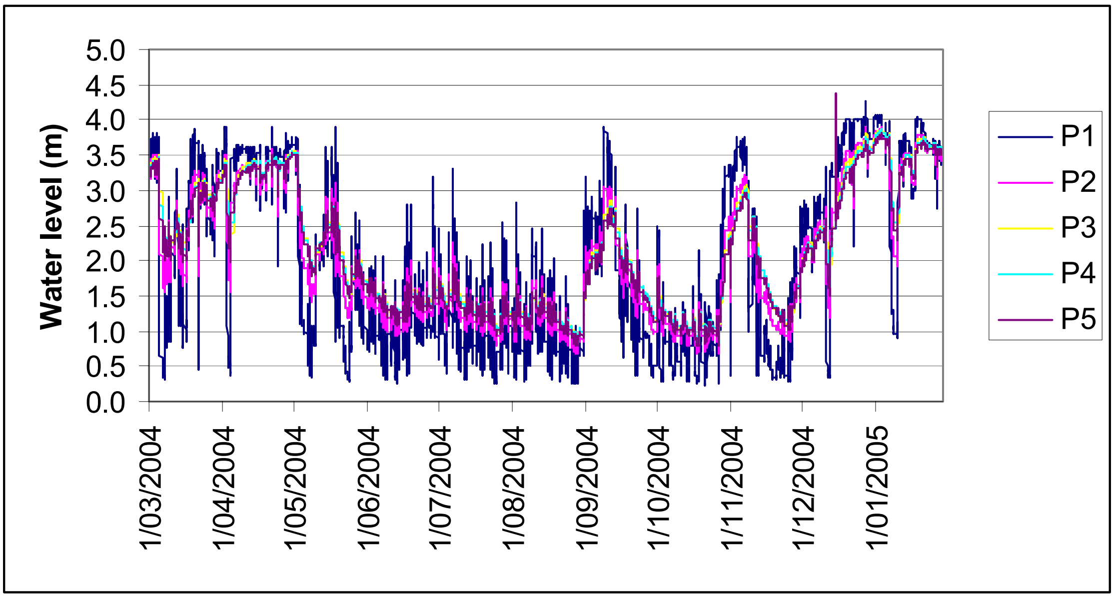


Figure 4.8. Piezometer data from zone 2 between 1 March 2004 and 6 Arpil 2005. Data interval is 15 min.

Similar to previous results, periods of high risk of seepage erosion correspond to power station shut down periods, generally following prolonged periods of 3-turbine power station operation. These events occurred during autumn 2004 (April, May) and again in Spring 2004 (October - March 2005). An extended high risk period occurred between 7–9 January 2005, coinciding with power station shut down during a large storm event. In-bank water surface slopes also exceeded 0.1 during the April 2005 monitoring weekend (2-3 April), consistent with the seepage features observed in the field.

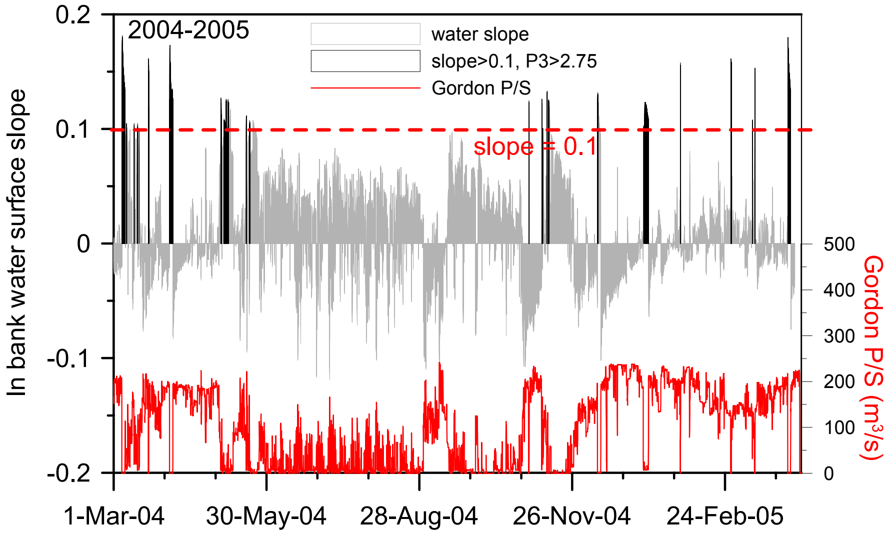


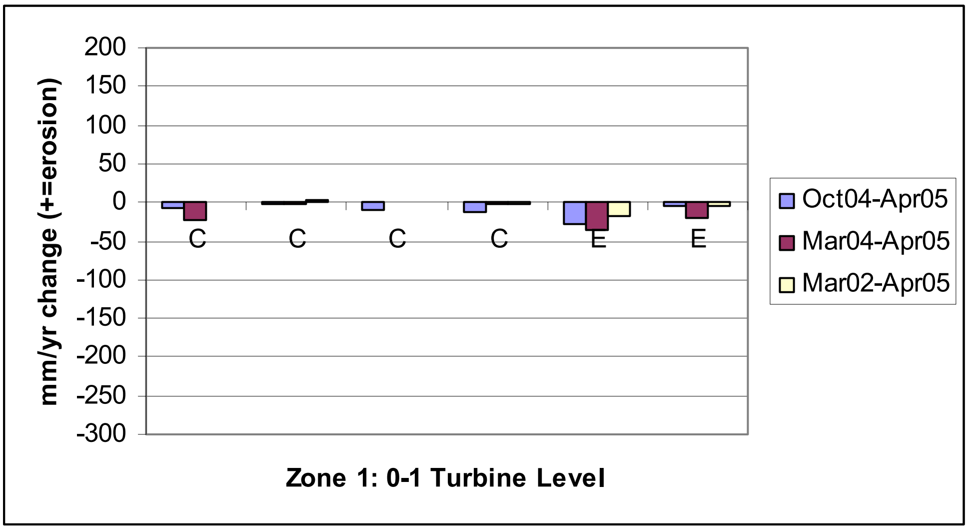
Figure 4.9. In-bank water surface slopes (upper) and discharge from Gordon Power Station (lower). Water slopes in excess of 0.1 are highlighted in black.

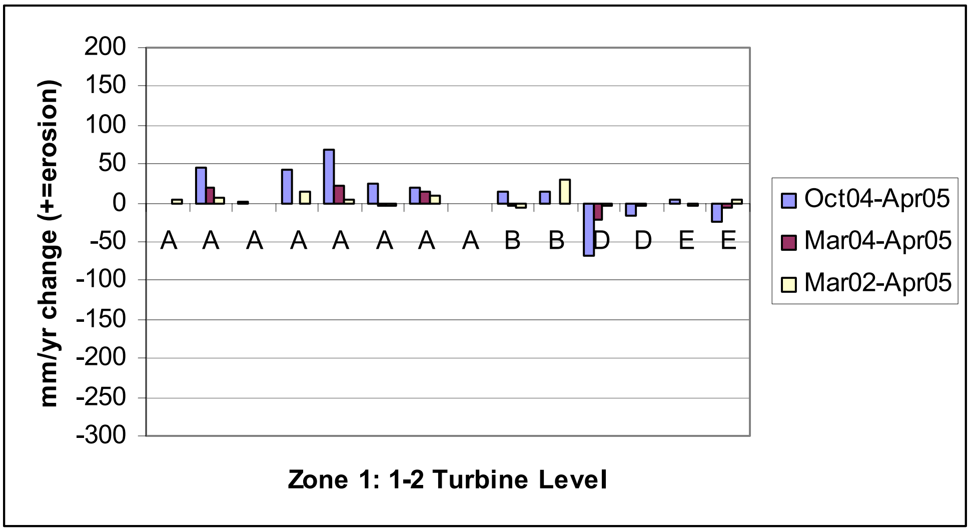
4.4.4 Erosion pins & scour chains

Erosion pins and scour chain results from the October 2004 and April 2005 monitoring are summarised in Table 4.2 to Table 4.6 and in Figure 4.10 to Figure 4.14.

Table 4.2. Summary of erosion pin results for zone 1.

Site	Description	Pin #	Change Mar 04-Oct 04 (mm)	Change Oct 04-Mar05 (mm)	Rate Oct 04-Mar 05 (mm yr^{-1})	Net Rate Mar 04 – Mar 05 mm yr^{-1})	Net Rate Mar 02 – Mar 05 (mm yr^{-1})	Date of Install.	Comments
1A	LB straight reach, series of pins along vertical colluvial bank behind cobble bar								
1A	wall / 1-2 turb	1	1	-1	-2.1	0.0	3.3	Dec-99	
1A	wall / 1-2 turb	2	-2	22	45.9	18.6	7.2	Dec-99	
1A	wall / 1-2 turb	3	-2	1	2.1	-0.9	0.0	Dec-99	
1A	wall / 1-2 turb	4	-23	21	43.8	-1.9	14.0	Dec-99	
1A	wall / 1-2 turb	5	-10	33	68.8	21.4	2.9	Dec-99	
1A	wall / 1-2 turb	6	-15	12	25.0	-2.8	-4.2	Dec-99	
1A	wall / 1-2 turb	7	7	9	18.8	14.9	9.1	Dec-99	
1A	wall / >3 turb	8a	12	3	6.3	14.0	-2.6	Dec-99	pipe casing
1A	wall / >3 turb	8b	1	7	14.6	7.4	-5.5	Dec-99	pipe casing
1A	wall / 2-3 turb	8c	2	4	8.3	5.6	0.3	Dec-99	pipe casing
1A	wall / 1-2 turb	9	-1	-1	-2.1	-1.9	-1.3	Dec-99	
1B	LB, pool, sandy alluvium over bedrock								
1B	Cavity / 1-2 turb	1	98	-66	-137.7	29.8	18.9	Nov-01	Long pin, Bank collapse
1B	Cavity / 2-3 turb	2	-17	-20	-41.7	-34.5	-26.4	Nov-01	
1B	Flow/ 1-2 turb	3	-10	7	14.6	-2.8	-7.2	Nov-01	
1B	Cavity / 2-3 turb	4	New pin	44	91.8	New pin	-6.5	Nov-01	New pin Oct 04, rate =Mar02-Mar04
1B	Toe / 1-2 turb	5	New pin	7	14.6	New pin	30.6	Nov-01	New pin Oct 04, rate =Mar02-Mar04
1C	LB inside bend, series of pins along toe of sandy alluvium over cobbles								
1C	Toe / 0-1 turb	1	-22	-3	-6.3	-23.3	0.0	Nov-01	
1C	Toe / 0-1 turb	2	-1	-1	-2.1	-1.9	2.9	Nov-01	
1C	Toe / 0-1 turb	3	5	-5	-10.4	0.0	0.0	Nov-01	
1C	Toe / 0-1 turb	4	3	-6	-12.5	-2.8	-2.9	Nov-01	
1D	RB, outside bend, cobbles & sands with cavities								
1D	Cavity	1	12	-13	-27.1	-0.9	11.4	Nov-01	
1D	Slope / 1-2 turb	2	9	-33	-68.8	-22.3	-3.6	Nov-01	
1D	Wall / 1-2 turb	3	3	-8	-16.7	-4.7	-1.0	Nov-01	
1D	Cavity	4	-9	-1	-2.1	-9.3	-6.5	Nov-01	
1E	LB straight reach u/s Abel Gorge, sandy alluvium, transect down bank								
1E	Wall / 2-3 turb	1	6	5	10.4	10.2	3.6	Nov-01	
1E	Wall / 1-2 turb	2	-2	2	4.2	0.0	-3.9	Nov-01	
1E	Slope / 1-2 turb	3	3	-11	-22.9	-7.4	4.9	Nov-01	
1E	Slope / 0-1 turb	4	-25	-14	-29.2	-36.3	-17.9	Nov-01	
1E	Toe / 0-1 turb	5	-19	-2	-4.2	-19.6	-4.2	Nov-01	
1E	slope / 2-3 turb	6	New pin	3	6.3	New pin		Dec-04	Pin added Dec 04
1E	slope / 2-3 turb	7	New pin	-1	-2.1	New pin		Dec-04	Pin added Dec 04
1F	RB straight reach u/s Abel gorge, alluvium & colluvium with cavities								
1F	Cavity / 2-3 turb	1	-448	77	160.6	-345.4	-149.9	Nov-01	Long pin
1F	Cavity / 2-3 turb	2	2	0	0.0	1.9	-3.6	Nov-01	
1F	Cavity / 2-3 turb	3	3	-36	-75.1	-30.7	-10.1	Nov-01	
1F	Cavity / 2-3 turb	4	47	-24	-50.1	21.4	-31.9	Nov-01	





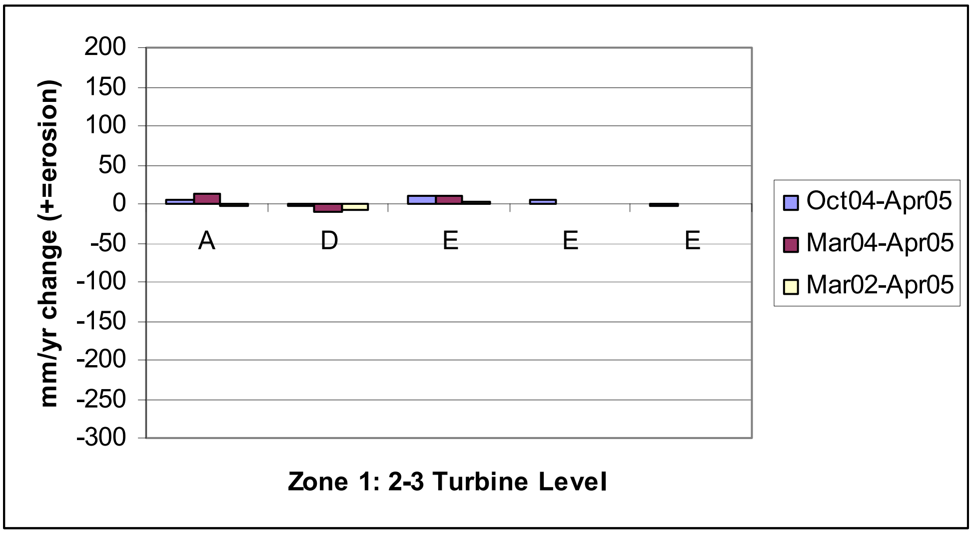
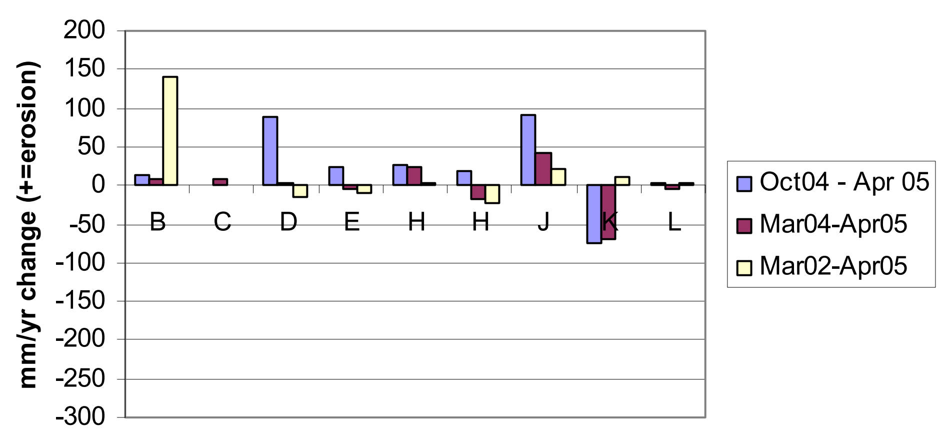


Figure 4.10. Erosion pin rates (mm yr^{-1}) for zone 1, showing rate for each pin in each turbine level over 3 time periods. Positive values indicate erosion, negative values indicate deposition.

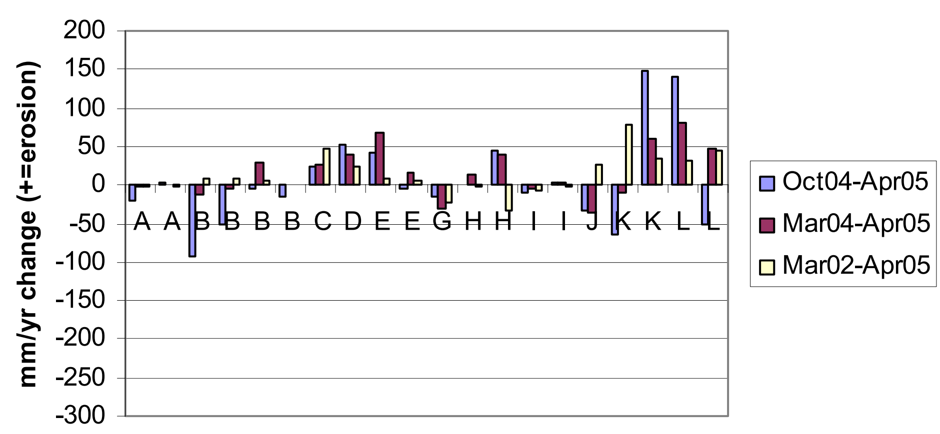
Table 4.3. Summary of erosion pin results for zone 2.

Site	**Description**	**Pin #**	**Change Mar 04-Oct 04 (mm)**	**Change Oct 04-Apr05 (mm)**	**Rate Oct 04-Apr 05 (mm yr^{-1})**	**Net Rate Mar 04 – Mar 05 (mm yr^{-1})**	**Net Rate Mar 02 – Mar 05 (mm yr^{-1})**	**Date of Install.**	**Comments**
2A	LB straight reach, transect from river side to backwater								
2A	Toe (Gordon side) / 1-2 turb	1	7	-10	-20.1	-2.7	-2.9	Nov-01	
2A	Slope / 1-2 turb	2	-2	2	4.0	0.0	-1.6	Nov-01	
2A	Slope / 2-3 turb	3	-2	-1	-2.0	-2.7	-5.2	Nov-01	
2A	Crest >3 turb	4	-5	0	0.0	-4.6	-1.6	Dec-01	
2A	b/slope / 2-3 turb	5	-3	2	4.0	-0.9	-2.9	Dec-01	
2A	b/slope / 2-3 turb	6	-1	1	2.0	0.0	-5.5	Nov-01	
2A	b/water / 2-3 turb	7	4	-2	-4.0	1.8	-2.6	Nov-01	
2B	RB straight reach, sands over bedrock, cavities								
2B	Flow / 1-2 turb	1	33	-46	-92.3	-11.9	9.4	Nov-01	
2B	Cav / 2-3 turb	2	-1	14	28.1	11.9	3.9	Nov-01	long pin
2B	Flow / 1-2 turb	3	20	-26	-52.1	-5.5	9.1	Nov-01	
2B	Cav / 2-3 turb	4	-12	36	72.2	22.0	5.5	Nov-01	long pin
2B	Flow / 1-2 turb	5	34	-2	-4.0	29.3	4.5	Nov-01	
2B	Cav / 2-3 turb	6	-4	15	30.1	10.1	-138.9	Nov-01	
2B	Flow / 1-2 turb	7		-7	-14.0		0.6	Nov-01	
2B	Toe / 0-1 turb	8	1	7	14.0	7.3		Oct-02	affected by seepage
2C	RB outside bend, sands over bedrock, cavities								
2C	Cav / 2-3 turb	1	266	-625	-1253.4	-328.4	-208.2	Dec-01	long pin
2C	Cav / 2-3 turb	2	-11	14	28.1	2.7	-17.5	Dec-01	long pin
2C	Slope / 1-2 turb	3	18	12	24.1	27.4	46.0	Nov-01	
2C	Toe / 0-1 turb	4				7.3		Oct-02	
2D	LB inside bend, sandy alluvium								
2D	Top / 2-3 turb	1	4	17	34.1	19.2	3.2	Nov-01	
2D	Slope / 2-3 turb	2	3	3	6.0	5.5	21.4	Nov-01	
2D	Slope / 1-2 turb	3	18	26	52.1	40.3	23.0	Nov-01	
2D	Toe / 0-1 turb	4	-42	44	88.2	1.8	-15.5	Nov-01	
2E	RB outside bend, alluvium, cavities								
2E	Cav / 2-3 turb	1	-3	11	22.1	7.3	7.4	Nov-01	
2E	Top / 2-3 turb	2	25	-18	-36.1	6.4	6.2	Nov-01	
2E	Slope / 1-2 turb	3	54	21	42.1	68.6	9.4	Nov-01	affected by seepage
2E	Slope / 1-2 turb	4	19	-2	-4.0	15.6	6.8	Nov-01	
2E	Toe / 0-1 turb	5	-17	12	24.1	-4.6	-9.7	Nov-01	Site 2F not monitored. In vertical cobble bank
2G	RB, beg of straight reach, sands over cobbles, cavities								
2G	Cav / 2-3 turb	1	-316	229	459.3	-79.6	96.2	Nov-01	long pin
2G	Flow / 1-2 turb	2	-25	-8	-16.0	-30.2	-22.7	Nov-01	
2G	Cav / 2-3 turb	3	11	-6	-12.0	4.6	2.6	Nov-01	
2G	Cav / 2-3 turb	4	103	64	128.4	152.8	54.7		long pin/measure error?
2G	Cav / 2-3 turb	5	-22	-321	-643.8	-313.8	-95.9	Nov-01	long pin
2G	Toe / 0-1 turb	6	55	-63	-126.3	-7.3	55.1	Oct 02	affected by seepage
2H	LB straight reach, sands, 2 transects of 3 pins.								
2H	Slope / 2-3 turb	1	12	3	6.0	13.7	-5.2	Nov-01	
2H	Slope / 1-2 turb	2	14	0	0.0	12.8	-1.0	Nov-01	

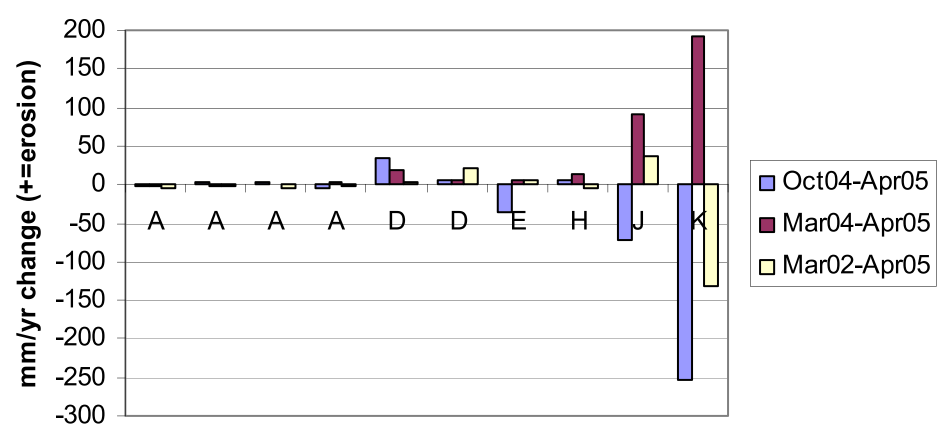
Site	**Description**	**Pin #**	**Change Mar 04-Oct 04 (mm)**	**Change Oct 04-Apr05 (mm)**	**Rate Oct 04-Apr 05 (mm yr^{-1})**	**Net Rate Mar 04 – Mar 05 (mm yr^{-1})**	**Net Rate Mar 02 – Mar 05 (mm yr^{-1})**	**Date of Install.**	**Comments**
2H	Toe	3	14	13	26.1	24.7	2.3	Nov-01	
2H	Cav / 2-3 turb	4	-6	26	52.1	18.3	2.3	Nov-01	
2H	Slope / 1-2 turb	5	20	22	44.1	38.4	-32.7	Nov-01	affected by seepage
2H	Toe / 0-1 turb	6	-27	9	18.0	-16.5	-23.0	Nov-01	
2I	LB straight reach, low slope alluvium w/ Ti Tree								
2I	Slope / 1-2 turb	1	-1	-5	-10.0	-5.5	-8.1	Nov-01	
2I	Toe / 1-2 turb	2	3	1	2.0	3.7	-2.9	Nov-01	
2J	LB outside bend, alluvium								
2J	Top / 2-3 turb	1	136	-36	-72.2	91.5	37.6	Dec-99	
2J	Slope / 1-2 turb	2	-23	-17	-34.1	-36.6	25.9	Dec-99	
2J	Toe / 0-1 turb	3	2	45	90.2	43.0	20.7	Dec-99	New pin Oct 02,
2K	LB outside bend, alluvium								
2K	Cavity / 2-3 turb	1	-143	-453	-908.5	-545.2	-193.7	Nov-01	long pin
2K	Flow / 2-3 turb	2	337	-126	-252.7	193.0	-131.5	Nov-01	
2K	slope / 1-2 turb	3	20	-32	-64.2	-11.0	77.1	Dec-99	new pin Oct 03,
2K	Slope / 1-2 turb	4	-7	74	148.4	61.3	34.0	Dec-99	new pin Oct 03,
2K	Toe / 0-1 turb	5	-39	-37	-74.2	-69.5	12.0	Dec-99	affected by seepage
2L	RB inside bend, sands, cavity								
2L	Cav / 2-3 turb	1	5	-4	-8.0	0.9	2.3	Nov-01	
2L	slope / 1-2 turb	2	19	70	140.4	81.4	30.8	Dec-99	
2L	Slope / 1-2 turb	3	76	-25	-50.1	46.7	44.0	Dec-99	
2L	Toe / 0-1 turb	4	-6	2	4.0	-3.7	3.9	Dec-99	



Zone 2: 0-1 Turbine Level



Zone 2: 1-2 Turbine Level



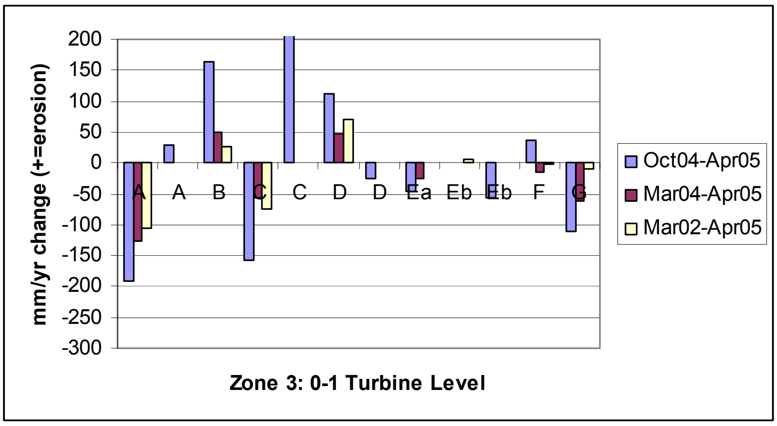
Zone 2: 2-3 Turbine Level

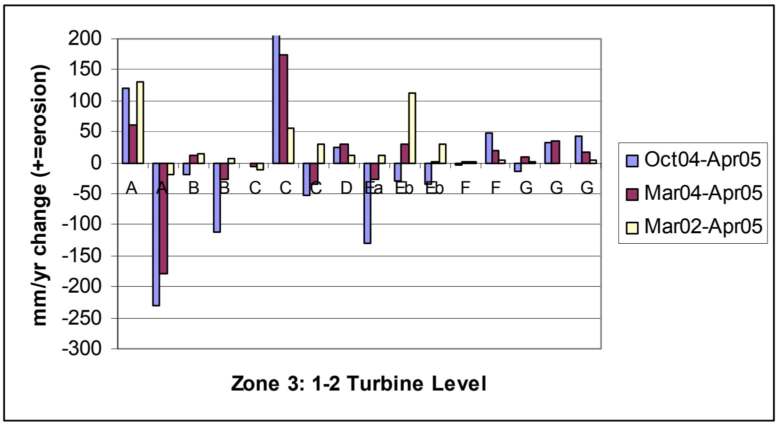
Figure 4.11. Erosion pin rates (mm yr^{-1}) for zone 2, showing rate for each pin in each turbine level over 3 time periods.

Table 4.4. Summary of erosion pin results for zone 3.

Site	Description	#	Change Mar 04-Oct 04 (mm)	Change Oct 04-Apr05 (mm)	Rate Oct 04-Apr 05 (mm yr^{-1})	Mar 04 – Mar 05 (mm yr^{-1})	Net Rate Mar 02 – Mar 05 (mm yr^{-1})	Date of Install.	Comments
3A	LB straight reach, sands over cobbles								
3A	slope / 1-2 turb	2	7	58	121.0	60.5	129.6	Oct-02	
3A	slope / 1-2 turb	3	-80	-111	-231.5	-177.8	-17.9	Oct-02	
3A	toe / 0-1 turb	4	-44	-92	-191.9	-126.6	-105.3	Oct-02	
3A	slope / 2-3 turb	5		-5	-10.4				
3A	slope / 2-3 turb	6		21	43.8				
3A	toe / 0-1 turb	55		14	29.2				
3B	LB, straight reach sands over cobbles, cavities								
3B	slope / 1-2 turb	1	22	-9	-18.8	12.1	14.3	Dec-99	
3B	cavity / 2-3 turb	2	3	-278	-579.8	-256.1	-105.9	Dec-01	affected by tree fall
3B	cavity / 2-3 turb	3	23	5	10.4	26.1	10.4	Dec-01	
3B	slope / 1-2 turb	4	25	-54	-112.6	-27.0	7.9	Dec-99	
3B	slope / 0-1 turb	5	-25	79	164.8	50.3	25.4	Dec-99	
3C	RB, straight reach, alluvium								
3C	cavity / 2-3 turb	1	-19	-60	-125.1	-73.6	-13.7	Dec 01	long pin/error in measurement?
3C	top / 1-2 turb	2	-5	-1	-2.1	-5.6	-12.1	Dec-01	
3C	slope / / 1-2 turb	3	0	186	387.9	173.2	56.7	Dec-01	
3C	slope / 1-2 turb	4	-13	-25	-52.1	-35.4	30.6	Dec-01	
3C	toe / 0-1 turb	5	16	-76	-158.5	-55.9	-73.7	Dec-01	affected by seepage
3C	toe / 0-1 turb	55		107	223.2				
3D	LB, straight reach, alluvium sand over cobbles, cobbles in back wall of bank								
3D	cavity / 2-3 turb	1	-79	22	45.9	-53.1	-9.1	Dec-01	
3D	slope / 1-2 turb	2	20	12	25.0	29.8	12.1	Dec-01	
3D	toe / 0-1 turb	3	-3	54	112.6	47.5	71.0	Dec-01	
3D	slope / 2-3 turb	4		-3	-6.3			Dec 04	
3D	toe/ 0-1 turb	55		-12	-25.0				
3Ea	RB straight bank sands with 5 pins in V-shape in gully								
3Ea	top	1	-6	9	18.8	2.8	-6.8	Nov-01	
3Ea	slope / 2-3 turb	2	31	3	6.3	31.7	46.9	Nov-01	
3Ea	Toe (base of gully)	3	-5	-22	-45.9	-25.1	1.6	Nov-01	
3Ea	slope / 1-2 turb	4	33	-62	-129.3	-27.0	12.1	Nov-01	
3Ea	top / 0-1 turb	5	-35	30	62.6	-4.7	4.9	Nov-01	
3Ea	slope / 2-3 turb	HW	0	0	0.0	0.0	0.0		
3Eb	RB straight reach, d/s 3Ea								
3Eb	top / >3 turb	1	-5	3	6.3	-1.9	-2.3	Nov-01	
3Eb	slope / 2-3 turb	2	-3	-3	-6.3	-5.6	-8.8	Nov-01	
3Eb	slope / 1-2 turb	3	46	-14	-29.2	29.8	111.1	Nov-01	
3Eb	slope / 1-2 turb	4	19	-16	-33.4	2.8	28.7	Nov-01	
3Eb	toe / 0-1 turb	5	0	0	0.0	0.0	5.2	Nov-01	
3Eb	slope / 2-3 turb	6		15	31.3				
3Eb	/ 0-1 turb	55		-27	-56.3				
3F	RB, straight reach, sands with cavity								
3F	cavity / 2-3 turb	1	780	484	1009.5	1176.9	423.3	Dec-01	long pin
3F	top / 1-2 turb	2	5	-2	-4.2	2.8	2.6	Dec-01	
3F	slope / 1-2 turb	3	-3	23	48.0	18.6	5.2	Dec-01	
3F	toe / 0-1 turb	4	-35	18	37.5	-15.8	-2.9	Dec-01	
3F	/ 0-1 turb	55	-3	7	14.6	3.7			

Site	Description	Pin #	Change Mar 04-Oct 04 (mm)	Change Oct 04-Apr05 (mm)	Rate Oct 04-Apr 05 (mm yr^{-1})	Net Rate Mar 04 – Mar 05 (mm yr^{-1})	Net Rate Mar 02 – Mar 05 (mm yr^{-1})	Date of Install.	Comments
3G	LB, straight reach, sands with cavity								
3G	cav / 2-3 turb	1	0	7	14.6	6.5	-0.7	Dec-01	
3G	top / 1-2 turb	2	16	-7	-14.6	8.4	0.3	Dec-01	
3G	slope / 1-2 turb	3	22	15	31.3	34.5	-0.3	Dec-01	
3G	slope / 1-2 turb	4	-3	21	43.8	16.8	3.6	Dec-01	
3G	toe / 0-1 turb	5	-14	-53	-110.5	-62.4	-10.1	Dec-01	pin freq underwater- difficult to measure





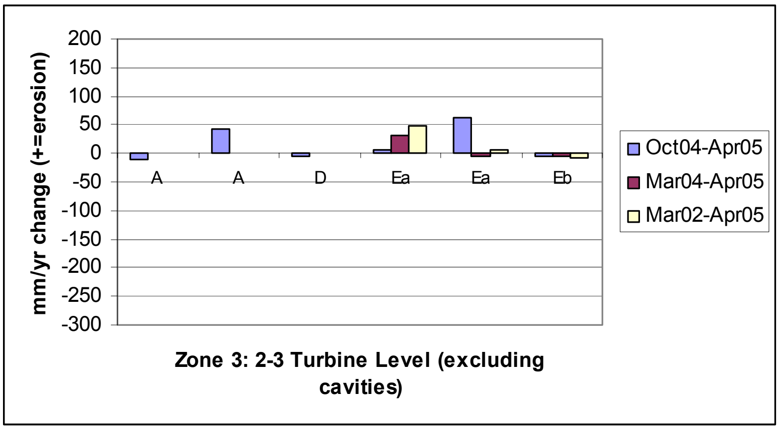
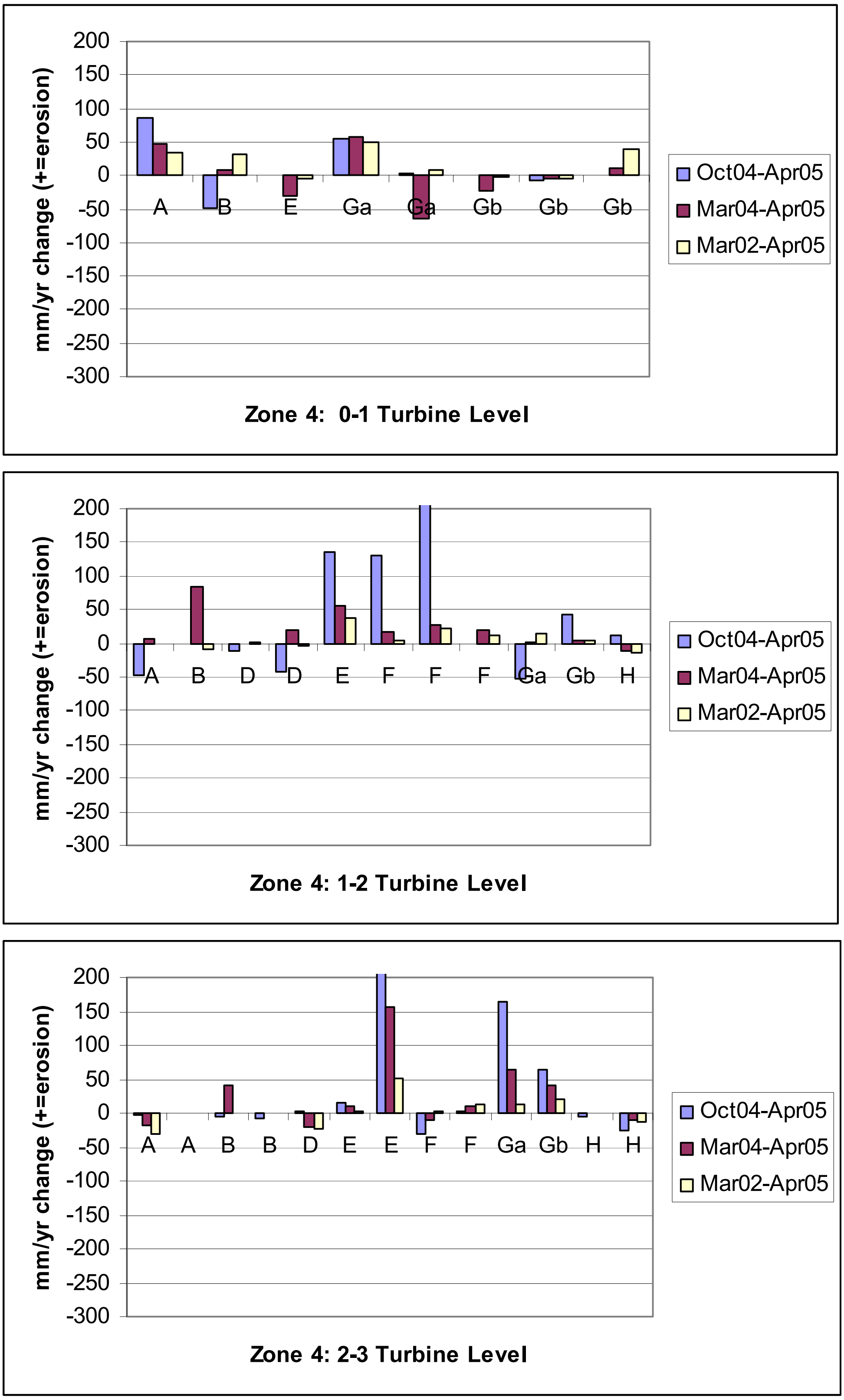


Figure 4.12. Erosion pin rates (mm yr^{-1}) for zone 3, showing rate for each pin in each turbine level over 3 time periods.

Table 4.5. Summary of erosion pin results for zone 4.

Site	Description	Pin #	Change Mar 04-Oct 04 (mm)	Change Oct 04-Mar05 (mm)	Rate Oct 04-Mar 05 (mm yr^{-1})	Net Rate Mar 04 – Mar 05 (mm yr^{-1})	Net Rate Mar 02 – Mar 05 (mm yr^{-1})	Date of Install.	Comments
4A	LB straight reach, sands								
4A	top / 2-3 turb	1	-18	-1	-2.1	-17.7	-29.7	Dec-01	
4A	slope / 1-2 turb	2	30	-23	-48.0	6.5	-1.6	Dec-01	
4A	toe / 0-1 turb	3	-57	64	133.5	6.5	61.6	Dec-01	
4A	slope / 2-3 turb	4		0	0.0			Dec-04	
4B	RB sands, cavity								
4B	top / 2-3 turb	1	47	-3	-6.3	41.0		Dec-01	lost Apr02, re-est Mar04
4B	slope / 1-2 turb	2				83.8	-8.8	Dec-01	Not found 10/04
4B	toe / 0-1 turb	3	27	7	14.6	31.7		Dec-01	Freq underwater, Lost Oct 02, re-estab Mar04
4B	slope / 2-3 turb	4		-2	-7.2			Dec-04	
4D	LB, beg inside bend sands over cobbles,								
4D	Top / 2-3 turb	1	-24	1	2.1	-21.4	-24.1	Dec-01	Lost Oct 02, re-est Mar04
4D	Slope / 1-2 turb	2	4	-5	-10.4	-0.9	0.3	Dec-01	Freq underwater
4D	slope / 1-2 turb	3	40	-20	-41.7	18.6	-4.2	Dec-01	
4E	LB, inside bend, sands								
4E	top / 2-3 turb	1	3	7	14.6	9.3	2.9	Dec-01	
4E	slope / 2-3 turb	2	18	151	314.9	157.4	52.5	Dec-01	
4E	slope / 1-2 turb	3	-6	65	135.6	54.9	37.5	Dec-01	
4E	toe / 0-1 turb	4	9	41	85.5	46.6	34.2	Dec-01	Freq underwater
4F	RB, inside bend, sands over bedrock								
4F	top / 2-3 turb	1	5	-15	-31.3	-9.3	2.9	Dec-99	
4F	slope / 2-3 turb	2	9	1	2.1	9.3	11.7	Dec-99	
4F	slope / 1-2 turb	3	-43	62	129.3	17.7	4.6	Dec-01	
4F	slope / 1-2 turb	4	-139	167	348.3	26.1	22.2	Dec-01	
4F	slope / 1-2 turb	5	20	0	0.0	18.6	12.1	Dec-01	
4Ga	LB straight reach, sands								
4Ga	top / 2-3 turb	1	-10	79	164.8	64.2	13.0	Dec-01	
4Ga	slope / 1-2 turb	2	28	-25	-52.1	2.8	15.7	Dec-01	
4Ga	slope / 0-1 turb	3	32	-23	-48.0	8.4	32.0	Dec-01	
4Ga	toe / 0-1 turb	4	-386	354	738.3	-29.8	-5.9	Dec-01	
4Gb	LB straight reach, sands; immed d/s 4Ga								
4Gb	top / 2-3 turb	1	13	31	64.7	41.0	20.9	Dec-01	
4Gb	slope / 1-2 turb	2	-17	21	43.8	3.7	4.2	Dec-01	
4Gb	slope / 0-1 turb	3	36	26	54.2	57.7	50.9	Dec-01	
4Gb	slope / 0-1 turb	4	-69	1	2.1	-63.3	9.5	Dec-01	
4Gb	toe / 0-1 turb	5				-22.3	-2.0	Dec-01	
4H	RB, u/s gorge entrance, sand over cobbles								
4H	top / 2-3 turb	1	1	-2	-4.2	-0.9	-1.0	Dec-01	
4H	slope / 2-3 turb	2	0	-12	-25.0	-11.2	-12.7	Dec-01	
4H	slope / 1-2 turb	3	-17	6	12.5	-10.2	-13.0	Dec-01	
4H	slope / 0-1 turb	4	-3	-3	-6.3	-5.6	-4.6	Dec-01	
4H	slope / 0-1 turb	5	12	0	0.0	11.2	39.5	Dec-01	



Zone 4: 0-1 Turbine Level

Zone 4: 1-2 Turbine Level

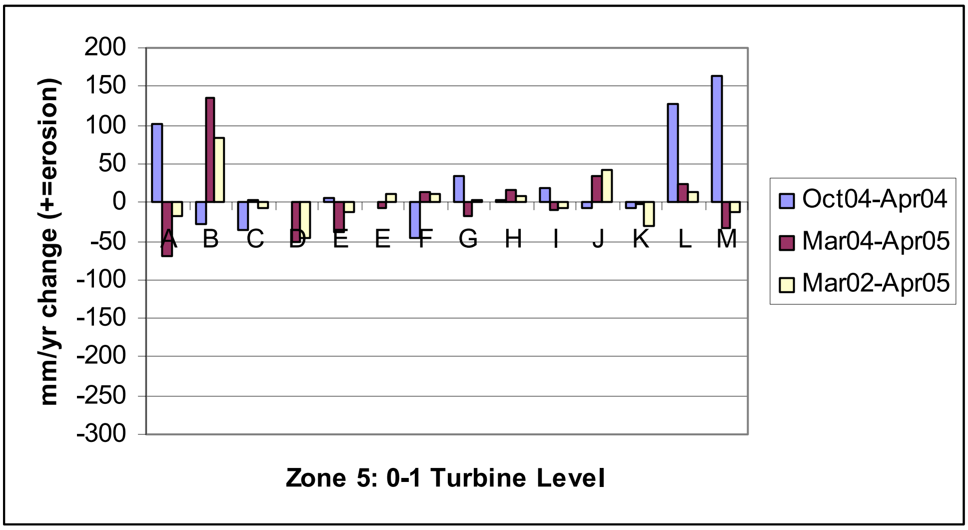
Zone 4: 2-3 Turbine Level

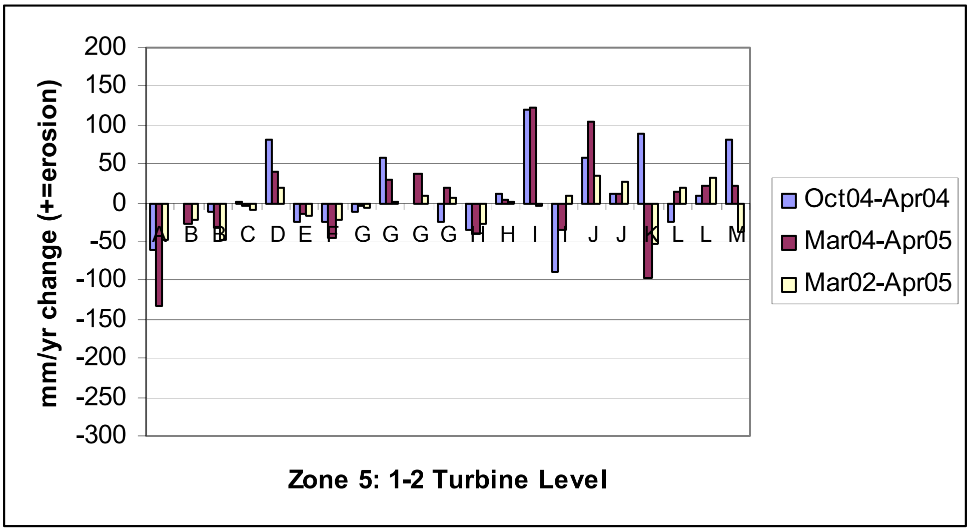
Figure 4.13. Erosion pin rates (mm yr^{-1}) for zone 4, showing rate for each pin in each turbine level over 3 time periods.

Table 4.6. Summary of erosion pin results for zone 5.

Site	**Description**	**Pin #**	**Change Mar 04-Oct 04 (mm)**	**Change Oct 04-Mar05 (mm)**	**Rate Oct 04-Mar 05 (mm yr^{-1})**	**Net Rate Mar 04 – Mar 05 (mm yr^{-1})**	**Net Rate Mar 02 – Mar 05 (mm yr^{-1})**	**Date of Install**	**Comments**
5A	RB, straight reach, sands,								
5A	Cavity / 2-3 turb	1					92.4	Dec-01	02-04 only
5A	cavity / 2-3 turb	2						Dec-01	
5A	slope / 1-2 turb	3	-114	-29	-60.5	-133.2	-47.0	Dec-01	
5A	toe / 0-1 turb	4	-124	49	102.2	-69.8	-17.9	Dec-01	u/water 10/04
5B	LB, inside bend, sands								
5B	top/2-3 turb	1	-19	-2	-4.17	-19.6	-4.2	Dec-01	
5B	slope / 1-2 turb	2	-28	0	0.00	-26.1	-22.8	Dec-01	
5B	slope / 1-2 turb	3	-30	-5	-10.4	-32.6	-47.3	Dec-01	
5B	toe / 0-1 turb	4	158	-14	-29.2	134.1	83.5	Dec-01	freq u/water
5C	RB, inside bend								
5C	top/2-3 turb	1	0	7	14.6	6.5	1.0	Dec-01	
5C	slope / 1-2 turb	2	-6	1	2.1	-4.7	-8.8	Dec-01	
5C	toe / 0-1 turb	3	19	-17	-35.5	1.9	-7.8	Dec-01	u/water 10/04
5D	RB, straight reach, steep								
5D	top/2-3 turb	1	8	6	12.5	13.0	-9.8	Dec-01	
5D	slope / 1-2 turb	2	3	39	81.3	39.1	19.6	Dec-01	
5D	toe / 0-1 turb	3				-52.1	-46.3	Dec-01	not found 10/04
5E	LB, straight reach, alluvium with grass								
5E	Cavity/2-3 turb	1	-10	18	37.5	7.5	44.0	Dec-01	collapse on pin 10/03
5E	Slope / 1-2 turb	2	-3	-12	-25.0	-14.0	-15.3	Dec-01	
5E	Slope / 0-1 turb	3	-43	3	6.3	-37.2	-12.1	Dec-01	
5E	toe / 0-1 turb	4				-6.5	11.1	Dec-01	not found 10/04
5F	LB, straight reach, sands with grass								
5F	Wall / 2-3 turb	1	0	9	18.8	8.4	3.5	Dec-01	reset mar03; net rate3/03-3/05
5F	Slope / 1-2 turb	2	-36	-11	-22.9	-43.8	-21.9	Dec-01	
5F	toe / 0-1 turb	3	36	-22	-45.9	13.0	10.1	Dec-01	u/water 10/04
5G	RB, straight reach, sands over cobbles behind cobble bar								
5G	Cavtiy/2-3 turb	1	7	-2	-4.2	4.7	6.9	Dec-99	
5G	slope / 1-2 turb	2	1	-5	-10.4	-3.7	-5.9	Dec-99	
5G	slope / 1-2 turb	3	3	28	58.4	28.9	1.3	Dec-99	
5G	slope / 1-2 turb	4	42	-1	-2.1	38.2	10.1	Dec-99	
5G	bench / 1-2 turb	5	33	-12	-25.0	19.6	7.8	Dec-99	
5G	toe / 0-1 turb	6	-36	17	35.5	-17.7	2.3	Dec-99	u/water 10/04
5H	RB, outside bend, steep sandy alluvium								
5H	top/2-3 turb	1	7	14	29.2	19.6	24.1	Dec-01	
5H	slope / 1-2 turb	2	-27	-17	-35.5	-41.0	-28.1	Dec-01	
5H	slope / 1-2 turb	3	-2	6	12.5	3.7	1.3	Dec-01	
5H	toe / 0-1 turb	4	15	2	4.2	15.8	8.2	Dec-01	u/water 10/04
5I	LB outside bend, sands								
5I	wall/2-3 turb	1	1	4	8.3	4.7	5.9	Dec-01	
5I	slope / 1-2 turb	2	74	57	118.9	122.0	-4.6	Dec-01	log against pin 10/04
5I	slope / 1-2 turb	3	6	-42	-87.6	-33.5	9.8	Dec-01	
5I	toe / 0-1 turb	4	-19	9	18.8	-9.3	-8.5	Dec-01	u/water 10/04
5J	RB, inside bend, sands								
5J	Top / 2-3 turb	1	-60	74	154.3	13.0	-13.7	Feb-02	

Site	**Description**	**Pin #**	**Change Mar 04-Oct 04 (mm)**	**Change Oct 04-Mar05 (mm)**	**Rate Oct 04-Mar 05 (mm yr^{-1})**	**Net Rate Mar 04 – Mar 05 (mm yr^{-1})**	**Net Rate Mar 02 – Mar 05 (mm yr^{-1})**	**Date of Install**	**Comments**
5J	slope / 1-2 turb	2	83	28	58.4	103.4	35.9	Feb-02	
5J	slope / 1-2 turb	3	8	6	12.5	13.0	26.4	Feb-02	u/water 10/04
5J	toe / 0-1 turb	4	41	-3	-6.3	35.4	41.1	Feb-02	u/water 10/04
5K	RB, outside bend, sands								
5K	slope / 2-3 turb	0	-258	178	371.3	-74.5			
5K	slope / 2-3 turb	1					-67.8	Feb-02	est 03/04
5K	slope / 1-2 turb	2	-146	43	89.7	-95.9	-53.8	Feb-02	completely buried 03/04, rate=03/02-03/04
5K	toe / 0-1 turb	3	2	-3	-6.3	-0.9	-29.4	Feb-02	
5L	LB, straight reach								
5L	Wall/2-3 turb	1	15	34	70.9	45.6	14.7	Feb-02	
5L	slope / 1-2 turb	2	27	-11	-22.9	14.9	19.9	Feb-02	
5L	slope / 1-2 turb	3	19	5	10.4	22.3	32.9	Feb-02	u/water 10/04
5L	toe / 0-1 turb	4	-35	61	127.2	24.2	14.7	Feb-02	u/water 10/04
5M	RB, outside bend								
5M	top / 2-3 turb	1	-57	-15	-31.3	-67.0	-43.4	Feb-02	
5M	slope / 1-2 turb	2	-14	39	81.3	23.3	-36.2	Feb-02	
5M	toe / 0-1 turb	3	-116	79	164.8	-34.5	-13.4	Feb-02	





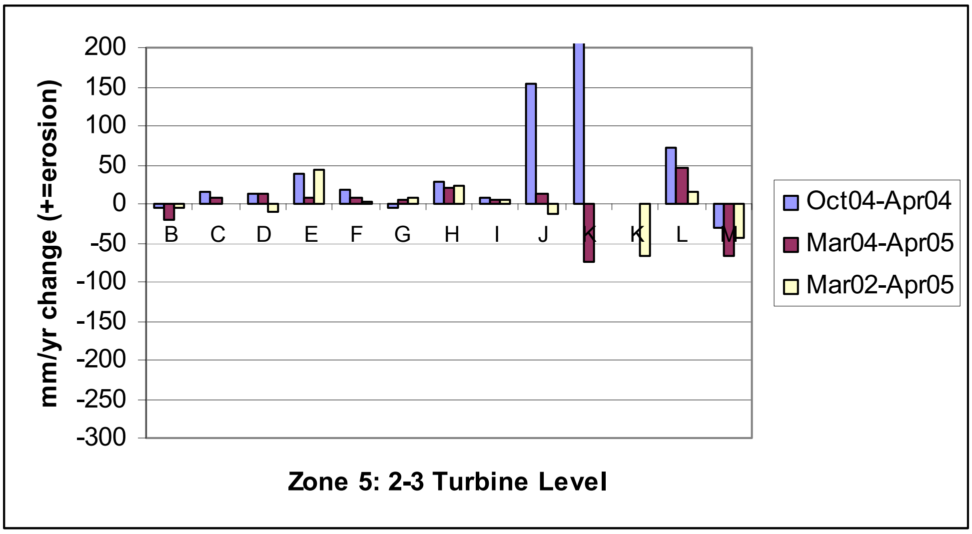


Figure 4.14. Erosion pin rates (mm yr^{-1}) for zone 5, showing rate for each pin in each turbine level over 3 time frames.

4.4.5 Photo-monitoring

Photo-monitoring of the 54 sites was completed in April 2005. Unfortunately, heavy rain and low cloud resulted in poor light conditions in zone 1. A summary of changes evident in the photos is presented in Table 4.7. Similar to previous years, the majority of sites showed no change at the scale of the photos. Of the sites that did show changes, most were located in zone 5 with an increase in vegetation on slip faces above the power station controlled high water level the most common observation.

Table 4.7. Summary of changes to photo-monitoring sites in April 2005.

Site	Change / Comment
P2-2a	Increased vegetation on slip upslope of power station controlled high water level
P2-3	Removal of vegetation at base of slip-below power station controlled water level
P2-4	Increased vegetation on slip upslope of power station controlled high water level
P4-2	Tree fall upslope of power station controlled high water level
P4-4c	Large log deposited in trees
P4-7	Increased vegetation growth on slip face upslope of power station controlled high water level
P5-2	Removal of vegetation at base of slip
P5-3	Increased vegetation growth on slip face upslope of power station controlled high water level
P5-6	Increased vegetation growth on slip face upslope of power station controlled high water level
P5-7	Removal of vegetation at base of slip
P5-8	Increased vegetation growth on slip face upslope of power station controlled high water level
P5-11	Increased vegetation growth on slip face upslope of power station controlled high water level
P5-16	Increased vegetation growth on slip face upslope of power station controlled high water level
P5-17	Removal of vegetation at base of slip and increased vegetation growth on slip face upslope of power station controlled high water level
P5-19	Increased vegetation growth on slip face upslope of power station controlled high water level

4.5 Discussion

The preparation of this report coincides with the preparation of the Basslink Baseline Report (BBR) which summarises and analyses 4 years of Basslink monitoring results. The BBR contains a detailed analysis of erosion pin results between 2002 and 2005, and links the findings to observations and processes on a zone by zone basis. The BBR is due for release in February 2006 and should be consulted for an in depth analysis of all pre-Basslink results to date. The results of the March 2004 – April 2005 monitoring year show the following trends which are consistent with the long-term findings:

- Piezometer results were consistent with power station operation, with high in-bank water surface slopes associated with power station shut down following extended 3-turbine discharge;
- High in-bank water surface slopes can be maintained following power station shut down if the shut down coincides with a large rain event;
- The erosion pin rates show high variability on a seasonal basis, with long-term rates (March 2002 – March 2005) lower for all zones;
- Zone 1 showed overall low erosion rates over both seasonal and annual time scales;
- Zones 2 showed increased rates of erosion with distance downstream, with the highest rates and variability associated with sites J, K and L. These sites are located upstream of the Splits, and are subjected to high water level changes (>4 m) due to backwater effects from the gorge.
- Zone 3 showed similar erosion rates as zone 2, with the greatest activity associated with the upstream portion of the zone. This reach is subject to backwater effects during high flows in the Denison River and low power station discharge. The high depositional rates in zone 3 are likely to be caused by sediment-bearing inflow from the Orange River entering the Denison backwater;
- In the 0-1 turbine bank level, zone 4 showed relatively constant rates of erosion (25 – 50 mm) over the Basslink monitoring period. In contrast, the 1-2 and 2-3 turbine zones showed greater variability, but lower net erosion rates over the 4 year monitoring period;
- Zone 5 showed greater variability and lower net erosion in the 0-1 turbine level compared to zone 4, but had similar results to zone 4 for the 1-2 and 2-3 turbine bank levels;
- Photo-monitoring results documented relatively few changes at the sites, with most changes associated with zone 5, and showing increased vegetation growth on slip faces.

5 Karst Geomorphology

5.1 Karst areas

Key karst features are monitored in both the Gordon-Albert and Nicholls Range karst areas twice per year. During 2004-05, monitoring trips were undertaken on the 9 October 2004 and 2 April 2005. Figure 5.1 shows the location of the two karst areas investigated by the monitoring program.

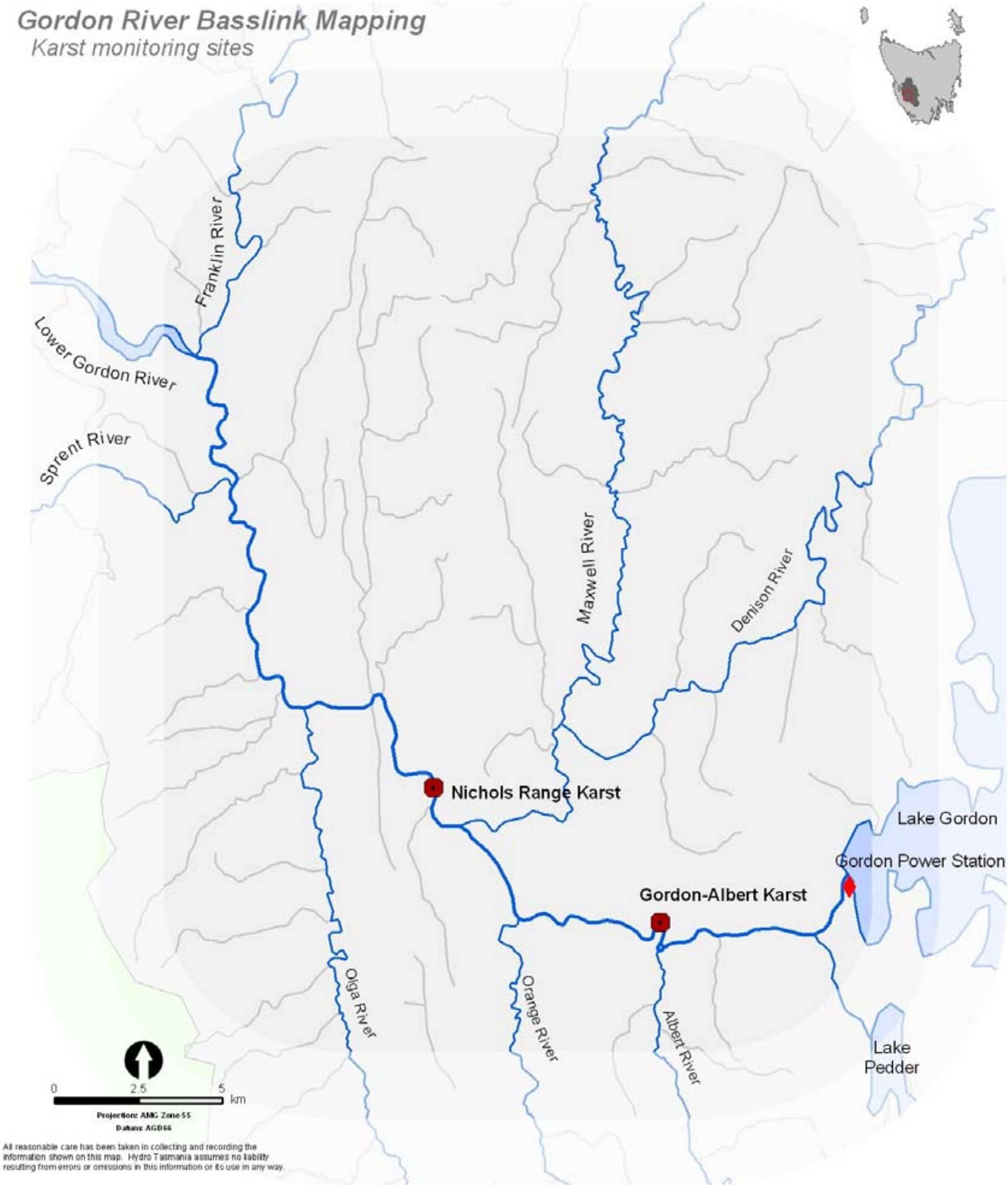


Figure 5.1. Map of the karst monitoring sites in the Gordon River.

5.1.1 Gordon-Albert karst area

There are 4 karst monitoring sites in the Gordon–Albert karst area. Site 1 is a backwater channel known as Channel Cam, site 2 is the GA-X1 cave with a doline at the entrance and sites 3 and 4 are dolines. Each site has a number of stainless steel erosion pins installed and a photo-monitoring site marked with a red metal peg. A water level recorder is installed in GA-X1.

The GA-X1 cave is 28 m long (including the large entrance area), 10 m deep and is located approximately 10–20 m from the Gordon River. There are two entrances to the cave: the smaller entrance lies on the western (river) side of the feature and is a short near-vertical shaft leading down into the main chamber; the second entrance is much larger and is effectively the base of a second large doline. The cave has a sump at its lowest level, which is at approximately the same level as the Gordon River.

5.1.2 Nicholls Range karst area

There are two karst monitoring sites in the Nicholls Range Karst area, site 5 in Kayak Kavern and site 6 in Bill Neilson Cave. Bill Neilson Cave contains a cave stream. Both sites were accessed by boat. Kayak Kavern has 5 erosion pins installed and a photo-monitoring site. Bill Neilson Cave site has 3 sub-sites within the cave which are designated 6A–C and comprise various arrays of erosion pins. There are also three lightweight capacitive water level probes deployed in the cave which are occasionally moved around for different monitoring purposes. Water levels are recorded every 20 minutes over a range of 1.0 – 1.5 m.

5.2 Methods and results

5.2.1 Erosion pin data

All erosion pins were measured to the nearest mm using a steel 300 mm ruler placed to the right side of the pin, on the contour level. Data for all sites are summarised in Table 5.1. Distances between the tops of the doline pins at sites 3 and 4 were also measured to assess whether any major structural change had occurred. The measurements are summarised in Table 5.2.

Several pins were replaced in 2004-05. During the October 2004 trip, a new erosion pin was installed at site 4 to replace the temporary green stick in the base of the doline, while in April 2005 a new pin (Pin 16) was placed at Kayak Kavern. The original pin had disappeared in 2003. Pins 29 and 30 at Kayak Kavern were not measured in October 2004 due to high water levels. The low levels in April 2005 enabled their measurement.

Table 5.1 Erosion pin data for karst sites from 2001 – 2005. Postitive change values indicate erosion, negative values indicate deposition.

Site no.	Site description	Pin no.	Length previous trips (mm)							Length 2/4/05 (mm)	Change this summer (mm)	Change in 12 months (mm)	Comments and interpretation
			23/11/01[a] or 8/12/01[b]	9/3/02	6/10/02	30/3/03	15/10/03	6/3/04	9/10/04				
1	Channel Cam	1 28	322[a] n/a	318 n/a	318 245	316 245	318 248	322 248	314 243	323 256	–9 –13	–1 –8	Significant loss of sediment over summer, more than accounting for sediment deposited in previous winter. Net loss over 12 months.
2	GA-X1 cave	2 3 4	250[a] 190[a] 154[a]	239 189 161	238 193 160	244 195 163	242 196 159	245 194 165	248 194 168	251 194 168	–3 0 0	–6 0 –3	Minor loss or no change over summer. Sediment lost over 12 months, except at highest pin (Pin 3) where no change was recorded.
	Doline at cave entrance	9 10	214[a] 278[a]	213 278	220 293	217 290	219 291	224 290	201 283	215 286	–14 –3	9 4	Loss of debris at both sites over summer, particularly Pin 9. Change partially offsets gains in the previous winter, but still imply a net gain over 12 months.
3	Doline adjacent to GA-X1	5 6 7 8	259[a] 300[a] 254[a] 195[a]	287 300 252 196	294 294 258 192	297 306 261 200	284 297 257 194	283 290 252 192	291 296 250 195	290 296 248 194	1 0 2 1	–7 –6 4 –2	Minor increase in debris over summer. Net decrease in debris over 12 months with larger changes towards the base of the feature.
4	Small doline	12 13 14 31 32	192[a] 234[a] 253[a] n/a n/a	171 238 256 n/a n/a	170 231 244 n/a n/a	172 217-245 262 n/a 	152 245 257 n/a n/a	155 241 257 n/a n/a	156 240 250 570 776	145 225 257 564 770	11 15 –7 6 6	10 16 0 n/a n/a	Increase in debris over summer at all pins except Pin 14, towards the top of the doline, which showed a reduction in debris. Pins 12 and 13 towards the base of the feature showed a net increase in debris over 12 months.
5	Kayak Kavern	16 17 18 19 29 30 33	309[b] 293[b] 267[b] 249[b] n/a n/a n/a	308 291 266 245 n/a n/a n/a	319 284 255 271 n/a n/a n/a	359 288 263 267 n/a n/a n/a	n/a 339 258 225 n/a n/a n/a	n/a 384 252 220 273 259 n/a	n/a 349 256 222 ? ? n/a	n/a 320 271 232 272 241 275	n/a 29 –15 –10 n/a n/a n/a	n/a 64 –19 –12 1 18 n/a	Sediment was lost over summer from the top flat section (Pins 18 and 19); nearly 3 cm of sediment was deposited on the steeper lower slope (Pin 17). A similar pattern was recorded over 12 months: the upper pins lost sediment, while the lower pins gained sediment (over 6 cm at Pin 17). Pins 29 and 30 which were below the water level in October 2004 were again observed. Pin 31 was installed to replace Pin 16, which disappeared in 2003.
6	Bill Neilson 6A at entrance	20 21 22	483[b] 300[b] 272[b]	480 299 272	499 302 269	495 301 272	501 304 271	493 305 271	502 301 270	497 300 271	5 1 –1	–4 5 0	Sediment deposited at Pin 20 close to stream level over summer, little change higher up bank (Pins 21 & 22). Sediment gain at Pin 20 did not offset erosion of 03 winter (9 mm) > small net loss over 12 months. Net gain of sediment at the mid level (Pin 21) and no change at upper level (Pin 22) for same period.
	6B Sed bank II	25 26 27	194[b] 203[b] 215[b]	195 203 216	195 202 214	195 202 213	198 202 212	198 204 208	205 206 210	203 204 210	2 2 0	–5 0 –2	Compared to last winter, some sediment was deposited over summer at the two lower pins (Pins 25 and 26). The highest pin (Pin 27) showed no change. Over the 12 months period there was a net loss at the lowest pin (Pin 25), no change at the middle pin (Pin 26) and a minor loss at the top pin (Pin 27).
	6C Dry sed bank	23 24	297[b] 227[b]	297 226	295 202	298 203	298 203	297 203	297 203	297 203	0 0	0 0	The results indicate no change over summer or over the preceding 12 months.

5.2.2 Water level recorders

5.2.2.1 Bill Neilson Cave

The hydrograph from the water level recorder measuring the cave stream flow in Bill Neilson Cave (BN) between 1 March 2004 and 1 September 2004 is shown in Figure 5.2. A section of this graph is enlarged in Figure 5.3 to display more detail of the changes during the high flow events in June-July 2004. This is the first season when data from the recorder at the entrance to the Bill Neilson Cave has been recovered. Figure 5.4 shows the hydrograph for the period of 9 October 2004 and 2 April 2005.

5.2.2.2 Cave GA-X1

The hydrograph from the water level recorder in GA-X1 between 1 March 2004 and 1 September 2004 is shown in Figure 5.5 together with the corresponding water levels at site72 (G5) for comparison. Figure 5.6 shows an enlarged portion of the hydrograph for the period between 10 April and 2 May 2004. Figure 5.7 shows the hydrograph for GA-X1 and corresponding water levels at site 72 (G5) for the period 9 October 2004 to 2 April 2005.

5.2.3 Photo-monitoring

Photographs were taken at all photo-monitoring sites as planned.

Table 5.2 Erosion pin survey data, doline sites 3 and 4.

Site No.	Pins measured	Distance between pins (m)					
		06/10/02	**30/03/03**	**15/10/03**	**06/03/04**	**09/10/04**	**02/04/05**
3	Photo-monitoring peg to Pin 5	3.28	3.295	3.295	3.295	3.298	3.300
	Pin 5 to Pin 6	1.055	1.055	1.05	1.055	1.050	1.050
	Pin 6 to Pin 7	1.35	1.345	1.345	1.355	1.359	1.356
	Pin 7 to Pin 8	1.85	1.85	1.85	1.845	1.852	1.850
	Sum Pins 5 to 8	*4.255*	*4.250*	*4.245*	*4.255*	*4.261**	*4.256*
4	Photo-monitoring peg to Pin 12	2.620	2.620	2.630	2.625	2.628	2.630
	Pin 12 to Pin 13	1.515	1.515	1.515	1.515	1.522	1.517
	Pin 13 to Pin 14	1.435	1.435	1.435	1.435	1.440	1.435
	Pin 13 to stick (Pin 31)	n/a	n/a	n/a	1.505	?	?
	Pin 12 to Pin 31	n/a	n/a	n/a	n/a	0.530	0.530
	Pin 12 to Pin 32	n/a	n/a	n/a	n/a	0.722	0.720
	Sum Pins 12 to 14	*2.95*	*2.95*	*2.95*	*2.95*	*2.962*	*2.952*

*Note that a different person read the numbers on the 9 October 2004 trip and this may be contributing to the slightly higher values. These values are still within the level of accuracy of the measuring technique and do not indicate any significant changes.

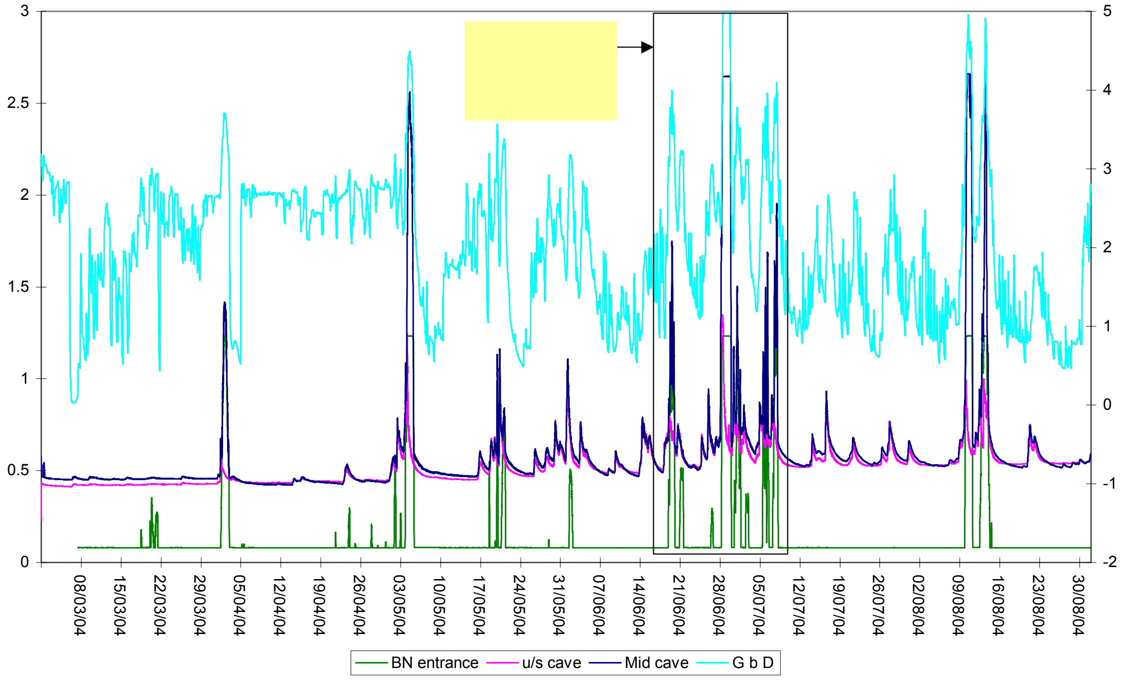


Figure 5.2. Bill Neilson cave water level recorder data (cave stream only, middle cave and cave entrance) together with the Gordon below Dension data for the period of 1 March 2004 to 1 September 2004. Data in metres above arbitrary zero levels. The middle cave recorder and the cave entrance recorder are relative to the same zero point, while the cave stream recorder has been offset by +0.213m to match up with the middle recorder.

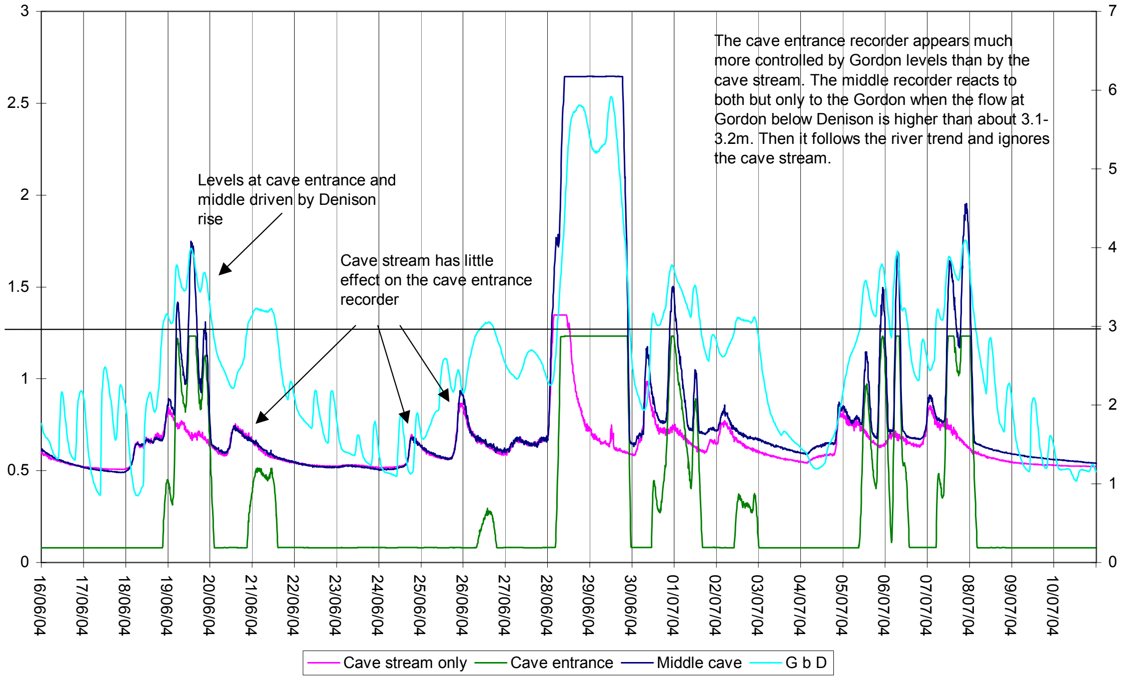


Figure 5.3 Three water level recorders in Bill Neilson Cave with Gordon below Denison water levels for the period 16 June to 11 July 2004. Data in metres above arbitrary zero levels. The middle cave recorder and the cave entrance recorder are relative to the same zero point, while the cave stream recorder has been offset by +0.213m to match up with the middle recorder. Note that the middle recorder may have moved slightly in the high flood at the end of June.

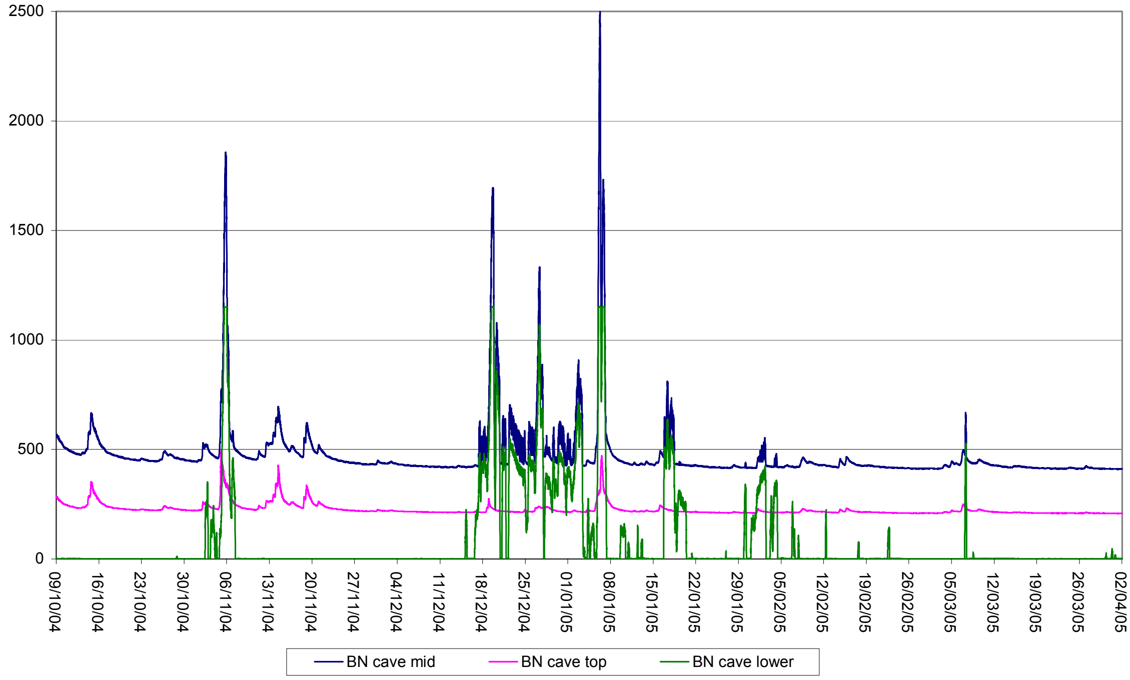


Figure 5.4 Bill Neilson cave water level (cave stream only: BN cave top; cave stream and Gordon River water backflooding: BN cave mid; Gordon River backflooding only: BN cave lower) for the period of 9 October 2004 and 2 April 2005.

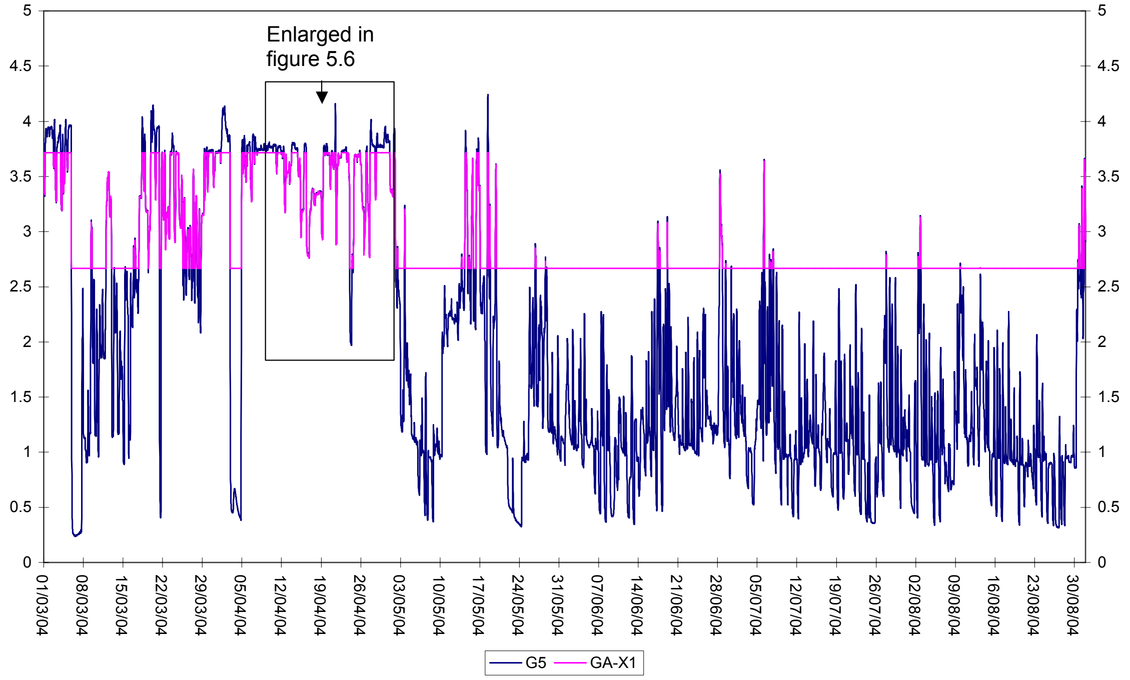


Figure 5.5 GA-X1 water level recorder with water levels from site 72 (G5) for comparison for the period of 1 March 2004 to 1 September 2004. Data in metres above arbitrary zero levels.

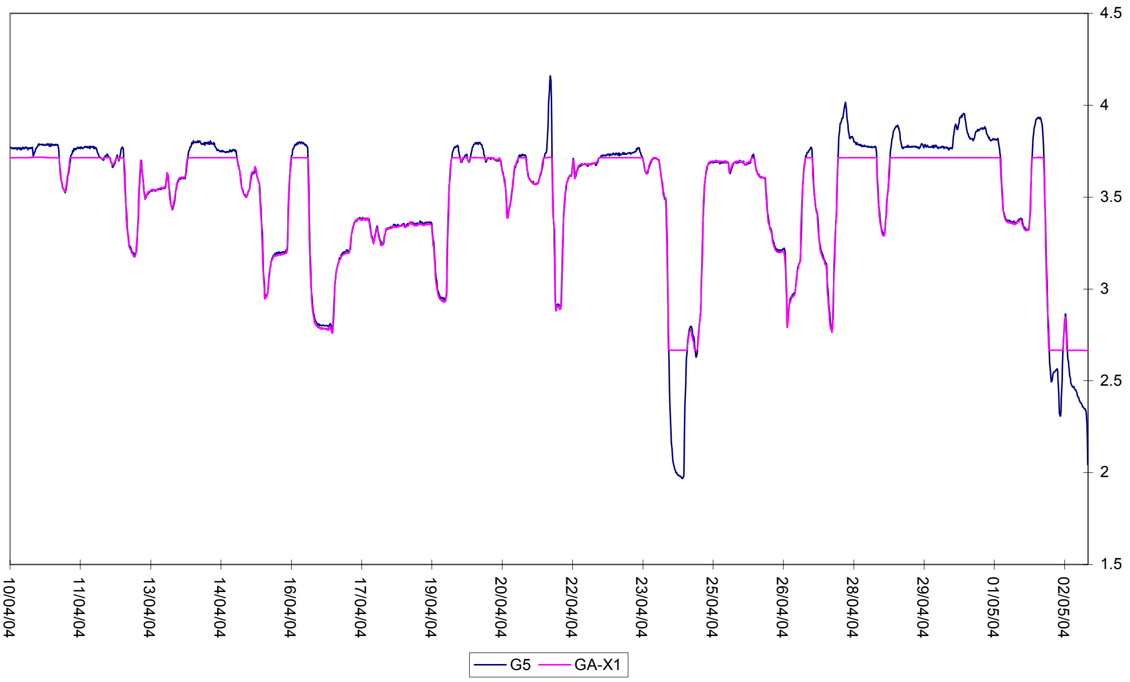


Figure 5.6 Enlarged section of water level recorder data from GA-X1 and site 72 (G5) for the period of 10 April to 2 May 2004.

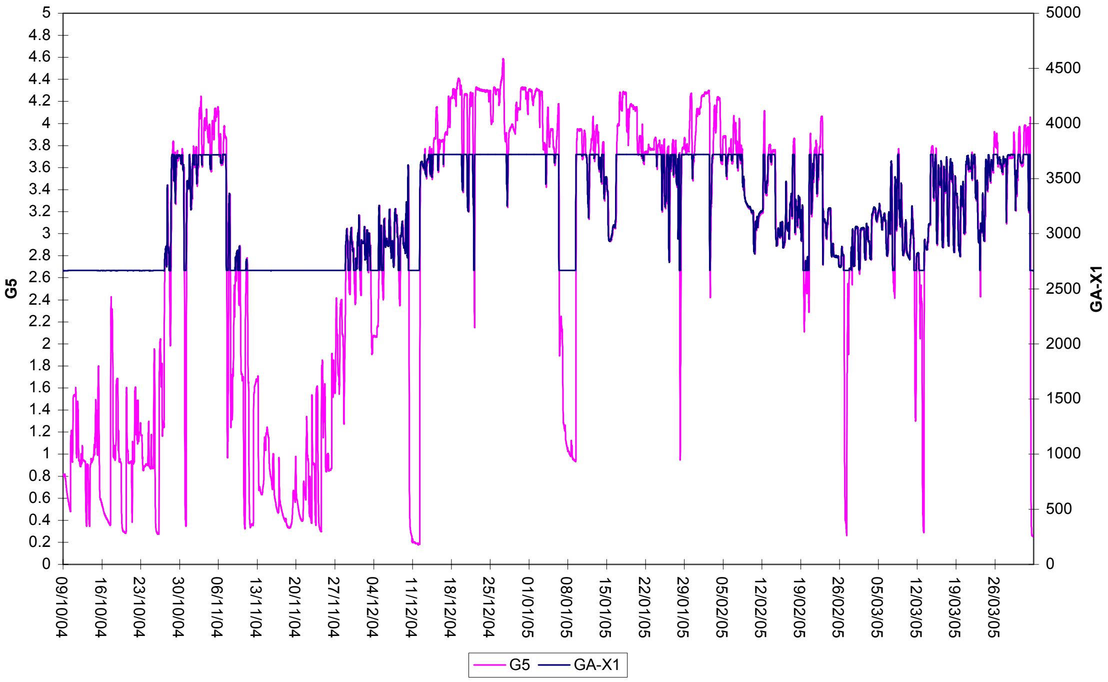


Figure 5.7 GA-X1 water level recorder with water levels from site 72 (G5) for comparison for the period of 9 October 2004 and 2 April 2005. Data in metres above arbitrary zero levels.

5.3 Discussion

5.3.1 Bill Neilson Cave

During the October 2004 monitoring few significant changes were observed in the Bill Neilson Cave. The three turbine operations at the power station occurred mainly in March, April and May and did not coincide with the high flow events in the Denison, so there were no unusually high flooding levels in the cave. A cave beetle and cave spider were found in the vicinity of site 6C while platypus scats were also discovered on the low platform on the right bank of the cave stream where it turns sharply to flow in a northerly direction.

During the April 2005 field trip, the large boulder which is used as a photo-monitoring reference point just inside the cave entrance was noted as being coated with about 10 mm of fresh dark mud. Platypus burrows and faeces were again observed along sediment banks well inside the cave. At least one burrow had been enlarged since the previous trip. A platypus was also seen in the Gordon River outside Kayak Kavern, a short distance upstream of the Bill Neilson Cave. The discovery of signs of platypus at Bill Neilson Cave corroborates recent observations suggesting that use of caves by platypus is more widespread than hitherto suspected (Munks *et al.* 2004).

5.3.1.1 Sediment transfer

There are three sets of erosion pin data in Bill Neilson Cave: the wet sediment bank in the entrance chamber; the wet sediment bank 5–10 m further into the cave; and the dry sediment bank 175 m into the cave.

For the first wet sediment bank at the entrance to the chamber, the October 2004 data showed that there had been 9 mm of erosion at the lowest level close to the cave floor during the preceding winter, resulting in a net loss of 1 mm over the last 12 months. The April 2005 data showed that deposition occurred at this site with 5 mm of sediment being deposited at the lowest level close to the cave stream (Pin 20). The resulting effect was a net loss of 4 mm over 2004-05. This is consistent with the emerging pattern whereby sediment accumulates close to stream level in summer, but is eroded away in winter. At the middle pin (Pin 21), the October 2004 data showed that 4 mm of sediment was deposited resulting in a 12-month net gain of 3 mm. This was the first time deposition was recorded at this pin after a winter period. The April 2005 data revealed a modest increase resulting in 5 mm being deposited in 2004-05. The pin at the upper level has shown little change over the winter period although a small but steady gain of just 1 mm in deposition has occurred over 12 months. There is no pronounced seasonal pattern higher up on the sediment bank at Pins 21 and 22 and the depth of these two pins has changed little since monitoring commenced in 2001.

At the second wet sediment bank, a seasonal trend of erosion during the winter and minimal change during the summer is emerging at the lowest pin (Pin 25). The October 2004 data revealed that there was 7 mm of erosion at the lowest level during winter. In contrast, the April data for 2005 showed that 2 mm of sediment was deposited over the summer. The result was a net loss of 5 mm over the 12 month period. At the middle pin (Pin 26), erosion of 2 mm occurred in the winter, based on the October 2004 readings, resulting in a net loss of 4 mm over the previous 12 months. The April 2005 data revealed deposition occurring in summer, resulting in a net loss of 2 mm for 2004-05. At the uppermost pin (Pin 27), the October 2004 data showed 2 mm of erosion (first time since the summer of 2001-02), which was not replaced in summer 2005 (April data), resulting in a net loss of 2 mm for 2004-05. Over the 4 years since monitoring commenced, there has been a net loss of 9 mm of sediment at the lowest pin, virtually no change at the middle pin and a 5 mm gain at the top pin.

In the dry sediment bank, there was no change in sediment deposition or erosion over the winter or summer periods which is consistent with results from previous years. The depth of sediment at the lowest pin (Pin 23) has been essentially unchanged throughout the monitoring period. Results for the upper pin (Pin 24) show a similar lack of variation with the exception of a 24 mm sediment gain recorded in 2002 which was thought to have been caused by interference from floating debris.

5.3.1.2 Photo-monitoring

Photo-monitoring sites have been established in the cave to support the erosion pin data in determining sediment transfer in the cave. During the October 2004 trip, photographs taken at site 6A near the cave entrance showed that a small pocket of erosion has occurred on the lee side of the base of Pin 20, similar to that which was evident in the October 2003 photographs. In addition, the rocks located in the bank at these lower levels appeared more washed in the October 2004 photographs compared to the previous field trip in March 2004. In contrast, there was no evidence of any major sediment shift at any of the monitoring sites during the April 2005 investigation. This supports the seasonal trend of erosion occurring during the winter months, followed by a period of deposition in summer.

5.3.1.3 Water level monitoring

In October 2004, water level data from the 3 recorders were retrieved for the first time for a winter period from the Bill Neilson Cave. The data revealed a small change in the relative baseflow measurements between the upstream and middle recorders which may be due to a slight shift in the downstream recorder during the high flow event in June 2004. The October 2004 data support the hypothesis that the middle recorder begins to be inundated by Gordon River water when the water at the Gordon below Denison recorder reaches a height of 3 m. Up until that point the water levels at the middle recorder correlate closely with those at the upstream cave recorder, but once the Gordon backflood waters reach the recorder, the water level fluctuations better reflect those in the river than in the cave stream. The height of the cave stream determines the height the river must be at before it can reach a given point in the cave. Analysis of the data sets from all three recorders showed that the middle cave and cave entrance recorders correlate most closely. Three flow events were recorded up until October 2004, when the middle recorder in the cave was completely flooded, the largest of which was on 29 June 2004 when the water level at the Gordon below Denison recorder reached 5.9 m. This is likely to have inundated the pins in the dry sediment bank although there were no corresponding sediment changes noted in the erosion pin data.

The April 2005 data revealed similar water level trends to previous summer periods. The trend was for relatively little natural pickup in the cave stream and the power station operating at high output levels for a significant proportion of the time (50% at three turbines). The effects of the consequent Gordon backwaters can be clearly seen in the data from the middle and lower recorders (Figure 5.4). The largest flood event recorded was on 6 January 2005 as a result of high flow in the Denison River, high levels in the local cave catchment in combination with high levels of power station discharge. The power station discharge was being simultaneously decreased from 3-turbine flow to 1-turbine flow resulting in a moderate sized backflooding event in the cave. However, this was not large enough to reach the pins in the dry sediment bank.

5.3.1.4 Conclusion

The seasonal pattern of winter erosion followed by summer aggradation of sediment has continued on the lower slopes of the first and second wet sediment banks in Bill Neilson Cave. This is due to the action of the cave stream under high energy winter flow conditions. Unusually, erosion occurred at slightly higher levels in the profile in the winter period. In contrast, modest or negligible sediment movement occurred at higher levels on the same sediment banks and there was no change at the dry sediment bank further into the cave. These findings are similar to the results of the 2003-04 summer and for most of the period since monitoring commenced.

The water level data were retrieved for the first time for a winter period and revealed that the cave entrance levels correlate more closely with the middle recorder and the Gordon River compared to the cave stream. The middle recorder correlates well with the upstream cave recorder until it is inundated by the Gordon River as water levels approach 3 m on the Gordon (below Denison gauge), whereupon it more closely reflects the Gordon River levels. Water levels retrieved in April 2005 revealed that the flow regime was similar in pattern to those of previous summer profiles. The peak flows in the cave during summer took place on 6 January 2005 as a result of high flows in the local catchment but these were not large enough to reach pins in the dry sediment bank. The high flows recorded in winter would have been large enough but the impacts of inundation on sediment deposition or erosion were likely to have been negligible.

5.3.2 Kayak Kavern

Water levels in Kayak Kavern varied between the October 2004 and April 2005 investigations. In October, water levels were higher than normal, due to high flow from the Denison River, resulting in water almost reaching the top of the active slope at Pins 17 and 19 in the cavern. These levels also prevented access to the erosion pins 29 and 30 (which were installed earlier in 2004) and resulted in the photo-monitoring being undertaken from slightly different locations. Water levels in

April 2005, were 1.5 m lower which enabled the confirmation that Pins 29 and 30 were still in place. A new pin (pin 31) was installed to replace Pin 16 which had disappeared in 2003. In April, the flat surface of the upper part of the sediment mound showed signs of current scouring, with patches of white sand exposed, whereas a layer of darkish mud covered the lower slopes in the vicinity of Pins 29–31. The slope showed evidence of cracking and minor slumps, particularly below Pin 19 in the active eddy area.

5.3.2.1 Sediment transfer

The winter of 2004 was a period of erosion in Kayak Kavern, with a 4 mm loss of sediment being recorded on the top of the silt mound (Pin 18) and 2 mm in the eddy (Pin 19). This is contrary to the winter period the previous year, when deposition occurred. The April 2005 data also recorded sediment losses for the summer of 15 and 10 mm for pins 18 and 19, respectively. The resulting effect was a net loss of 12-19 mm over the 2004-05 period. The depth of sediment at Pin 19 is 17 mm above that when monitoring commenced in December 2001, which is mainly attributable to the 42 mm of sediment deposited in the winter of 2003. Pin 18, which has had sediment changes varying across a range of 19 mm since the program began, yielded more consistent results and is probably most representative of average sediment transport conditions in the cave. Slumping of material on the slope in the eddy area at Pin 19 was probably a more significant transport mechanism than scouring, whereas the opposite is likely at Pin 18. Disturbances caused by traversing the soft sediments on the slope when measuring the pins may also be contributing to the instability of the slope.

The steeper slope at Kayak Kavern again experienced significant sediment transfer in winter and summer, with 35 mm of sediment deposited at Pin 17 in October 2004 and a further 29 mm of new sediment being recorded in April 2005. The net gain in sediment for 2004-05 was 64 mm. This is likely to be due to slumping of material around the pin. The sediment surface around the base of the pin is now uneven with significantly more of the pin exposed on the left side relative to the contour level. Since December 2001, results for Pin 17 have varied across a range of 100 mm. Most of this is due to 96 mm of erosion that occurred between March 2003 and March 2004. Despite recent sedimentation, the height of the surface at Pin 17 is still 27 mm lower than at the commencement of monitoring. While the continuity of data for other pins on this slope is poor, two other pins corroborate the evidence from Pin 17 that this location is currently undergoing a period of aggradation, at least over the last 12 months. Although, data for Pins 29 and 30 was lacking in October due to high water levels, results from April 2005 indicate a 1–18 mm increase in the depth of sediment.

Regular seasonal trends are not evident in Kayak Kavern. Pin 16 has fallen out, Pin 17 is close to falling out and sediment transfer processes at the remaining 2 long standing pins, 18 and 19 are variable, relative to each other, and from season to season.

5.3.2.2 Photo-monitoring

Photo-monitoring of Kayak Kavern in October 2004 revealed no significant changes, whereas in April 2005 some minor slumping in the vicinity of Pin 19 was evident when comparisons were made with photos from previous monitoring.

5.3.2.3 Conclusion

The upper surface of the sediment mound at Kayak Kavern experienced erosion in winter and summer for 2004-05. The winter erosion was contrary to that recorded in the winter of 2003, when deposition had occurred. A similar trend in erosion also occurred at the higher levels of the eddy slope at Pin 19, progressively reducing the depth of sediment in the wake of a significant flux of sediment in winter 2003. In contrast, the lower slopes have been subject to slumping and aggradation with 64 mm of sediment accumulating at Pin 17 during 2004-05. Results obtained to date at Kayak Kavern point towards episodic sediment fluxes rather than distinct seasonal trends.

The monitoring trip in April 2005 revealed that disturbance of the soft sediments while measuring pins at Kayak Kavern needs to be considered and all pins and survey points need to be retagged ahead of the post-Basslink monitoring phase to facilitate identification. Most pins are currently identified from their mapped positions.

5.3.3 GA-X1

No significant changes were observed in GA-X1 in winter or summer for 2004-05. In October 2004, the thick stick used as part of the original survey in the doline at the cave entrance was found to have fallen over. In April 2005, a solution feature in the dolomite in the river channel close to the GA-X1 cave was observed. The feature comprised of a pipe-like hole about 0.5 m in diameter that extended into a cliff that forms the riverbank. It is possible that this conduit is a pathway for movement of water and sediment between the river and the cave. This feature was mapped during the original investigation in 2000 but was not linked to GA-X1. At the time as the cave had not yet been discovered.

5.3.3.1 Sediment transfer

In the doline at the cave entrance, debris had accumulated in October 2004 with 23 mm and 7 mm increases measured at pins 9 and 10, respectively. The resulting net gain for the 12 month period from the previous winter was 18 and 8 mm for pins 9 and 10, respectively. In contrast, the April 2005 data showed a reduction in debris of 3-14 mm for pins 9 and 10. This partially offset the increases recorded in the preceding winter. The resulting effect on net levels for 2004-05 were increases of 4-9 mm. These results still indicate that the surface is lower by 1-8 mm compared to November 2001, when the pins were emplaced.

Inside the cave, the October 2004 data revealed that 3 mm of erosion had occurred during winter at both the lower (Pin 4) and middle pins (Pin 2). This resulted in a net change from the previous winter of -9 mm and -6 mm for Pins 4 and 2, respectively. The erosion in winter 2004 was contrary to the typical winter deposition in this cave. At the highest level, Pin 3, no change was evident over the winter. The April 2005 data revealed no change at the highest and lowest pins and therefore negligible loss of sediment during 2004-05. The middle pin recorded 3 mm of erosion which continues the trend of sediment removal first evident in 2002. Pin 2 is now 1 mm lower than at the commencement of the monitoring program. As noted in previous reports, there has been a steady net loss of material at all pins in the cave since the beginning of the program with the most significant surface lowering of 14 mm occurring at the lowest pin.

5.3.3.2 Water level monitoring

Water level data from GA-X1 and site 72 (G5) are shown in Figure 5.5 and Figure 5.7 for the downloads of October 2004 and April 2005, respectively. The winter data set displays good correlation between GA-X1 with an offset of +2.665 m and site 72 (G5). The Gordon River water levels fluctuated considerably more within the cave zone in the 2004 winter compared to previous winters, despite several months of the power station operating at just 1 or 2 turbines. This is likely to be the reason why the erosion has occurred at the lower levels in the cave, instead of the typical winter deposition. The April 2005 summer data shows that water level fluctuations within the cave were predominantly at mid to high levels, consistent with the high proportion of time the power station was operating at 2 and 3-turbine levels (approximately 75% of the time). The minor erosion at the middle pin (Pin 2) detected in April, is likely to be due to the relatively high fluctuating water levels that prevailed during the summer periods. The lowest pin (Pin 4) would have been consistently under water for the majority of the period and hence protected from erosion, while Pin 3 is outside the typical range of inundation.

5.3.3.3 Conclusion

Net erosion within the active levels inside GA-X1 was measured during winter. This is in contrast to previous winters which have been predominantly periods of deposition. This is considered to be due to the higher percentage of time that the river level was fluctuating within the cave compared to previous years. The April data indicated no loss of sediment at the lower and upper levels but there was minor erosion recorded at the mid level, which is likely to be due to the fluctuating Gordon River and associated water levels in the cave at or about this level. These results are consistent with a pattern of slow change, typically in the direction of surface lowering, which is evident in the data since monitoring commenced. The entrance doline is not inundated by the river and yields more variable erosion pin results which are likely to be dictated by variations in the depth of forest litter rather than movement of the underlying soil. Whereas last winter saw an increase in the height of the surface, this was partially offset by a reduction over the summer.

5.3.4 Dolines

There are two doline sites being monitored in zone 2: Site 3 adjacent to GA-X1; and site 4 adjacent to Channel Cam.

The erosion pins in site 3 are arranged with Pin 5 in the base of the depression with a succession of pins arrayed in a line at 1–2 m distances apart up to Pin 8. Three of the pins showed that a loss of debris occurred, while Pin 7 on the wall of the feature showed that debris has accumulated over the winter, based on the October 2004 sampling. The distances between the tops of the pins were comparable to previous monitoring trips (within the level of operator error given that the operator changed during this period) and indicated that there has been no appreciable movement or change in the structure of the feature since the previous trip or, indeed, since the pins were installed. The April 2005 monitoring trip revealed a minor or negligible increase (0-2 mm) in debris over summer. For three of the four pins, this contrasts with a reduction in the height of debris recorded in October 2004, contributing to a net reduction for 2004-05.

Five erosion pins are now installed in the doline at site 4. These include: 3 original pins (Pin 12 at the base of the depression and Pins 13 and 14 up the side); the temporary green stick in the base of the feature, which is Pin 31; and a new pin, labeled Pin 32, at the base of the feature, installed during the October 2004 trip. The new pin is 776 mm high and 722 mm from Pin 12 (based on 'top of pin' measurements). The October data revealed an accumulation of debris at pins 13, 14 and 31, while at Pin 12 there was a slight loss of material. There was also no significant change in the distances between the pins, indicating no appreciable change in the structure of the feature, either since the last sampling period or since the pins were installed. The April 2005 data revealed the accumulation of debris at pins 12, 13, 31 and 32 in the range of 6-15 mm. This was most significant at pins 12 and 13 which are closest to the feature. In most cases this is consistent with the pattern over the preceding winter and the 12 months as a whole. The fifth pin, Pin 14 which is closest to the rim of the feature, was the only pin to show a loss of material this summer, balancing the gain over the preceding period to give zero net change over 2004-05.

No strong seasonal trends are emerging in the changes in debris accumulation and decay at the pins in either of the dolines. The largest changes recorded since monitoring commenced in November 2001 were at Pin 12, where 47 mm of debris has accumulated. This pin is located at the base of the doline where litter would be expected to accumulate more rapidly than on the slopes. It is probable that changes in the height of the erosion pins at both dolines can be attributed to variations in the depth of forest litter rather than a loss or accumulation of the underlying soil. Consistent with previous trips, measurement of distances between the tops of the pins at sites 4 and 5 did not indicate a significant change, within the precision of the method. This suggests that the morphology of the dolines has remained stable since the monitoring program commenced.

5.3.5 Channel Cam

The erosion pins at Channel Cam both recorded significant deposition with 8 mm occurring at Pin 1 and 5 mm at Pin 28 in October 2004. This is in contrast to the previous winter period which was one of erosion. The change in sediment transfer processes to deposition in the winter of 2004 is likely to be due to the change in frequency and extent of inundation compared to the winter of

2003. The water level at site 72 (G5) exceeded the 4.1 m trigger level for inundation of the channel on only four occasions and for very limited periods, all of which occurred during the autumn months (see Figure 5.3). This is in comparison to more than 5 weeks of inundation and water level changes during the 2003 autumn-winter. No significant changes were evident from the photo-monitoring undertaken in October 2004.

In contrast to the winter results, monitoring in April 2005 revealed that significant erosion was evident at pins 1 and 28 during summer with the surface being lowered by 9-13 mm. This is likely to have been caused by the relatively high proportion of time the channel was inundated this period (approximately 23% of the time) and the water level fluctuations within the channel zone. Both pins indicate a modest net loss of sediment since monitoring commenced amounting to 1 and 8 mm at pins 1 and 2, respectively.

6 Riparian Vegetation

6.1 Introduction

The riparian vegetation monitoring program collected data on the cover and abundance of vascular riparian species at permanent plots located both in the middle Gordon River and in two reference rivers, the Franklin and Denison. Analysis of these data will provide:

- a greater understanding of the existing processes, trends and condition of riparian vegetation within the middle Gordon River;
- datasets to quantify any potential effects of the Basslink project; and
- a scientific basis for adaptive management.

This section provides results of the December 2004 and April 2005 monitoring. The locations of the monitoring sites are shown in Figure 6.1. Site numbering is consistent with the fluvial geomorphology zone system (see Figure 4.1). There are no riparian vegetation monitoring sites in zone 1.

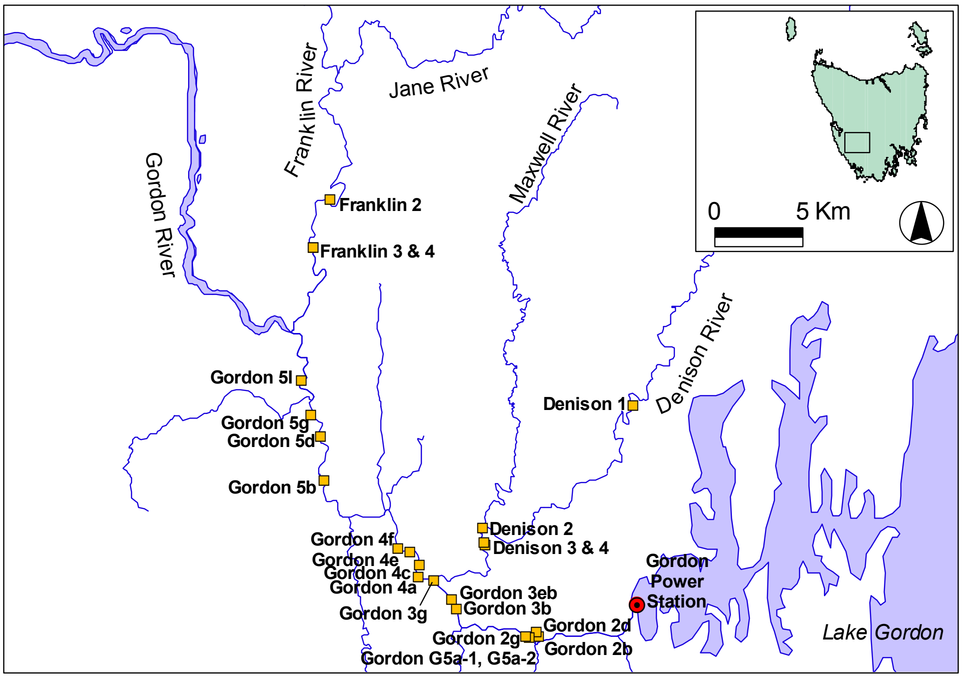


Figure 6.1 Map of the riparian vegetation monitoring sites in the Gordon, Denison and Franklin Rivers.

6.2 Methods

6.2.1 Field monitoring

The summer (December 2004) data collection included assessment of seedling recruitment and photo-monitoring on the Gordon River. Details of the full monitoring program are given in the Gordon River Basslink Monitoring Annual Report 2002-03 (Hydro Tasmania 2003). The trip also included seedling monitoring at the tributary sites. The autumn (April 2005) data collection included assessment of vegetation cover and seedling recruitment in the Gordon River sites and in the Franklin and Denison Rivers.

6.2.2 Quadrat location

Quadrat sites were located along riverbanks adjacent to sites established for geomorphic studies to enable investigation of correlation between geomorphic investigations and vegetation processes. A full description of the geomorphic monitoring is given in Chapter Six. Vegetation sites are not present at all geomorphology sites due to the need to locate vegetation sites in 'relatively' stable areas where sites are likely to persist over the sampling time. Therefore, sites have not been located in areas of overhangs or active scour.

Bank sampling sites were established in four of the five zones of the Gordon River (see Figure 6.1). These zones correspond with those determined in initial geomorphic studies (Koehnken *et al.* 2001) which), which divided the Gordon River into five zones based on previous studies and hydrologic controls such as gorges and constrictions. No bank sites were established in zone 1, the zone closest to the power station, as it is dominated by bedrock substrate with little substrate suitable for vegetation.

Site selection within the Denison and Franklin Rivers was largely dictated by logistical constraints; only those sites accessible by helicopter under a range of flow levels (except very high flows) were selected for quadrat sites. This resulted in all bank monitoring sites being adjacent to, or accessible from, cobble bars.

6.2.3 Sampling design

At each site one permanent transect, comprising eight one-metre square quadrats was established. Quadrats were offset by 0.5 m from the transect line to avoid trampling impacts and located with reference to the high water mark as shown in Figure 6.2. At most of the quadrat sites the high water mark was delineated by a star picket previously installed during full power station (three turbine) operation. At sites where there was no clear delineation of high water mark this was estimated by changes in litter cover and ground disturbance. Sites were permanently marked using deck spikes and flagging tape at the landward end of the transect and deck spikes in all quadrat corners.

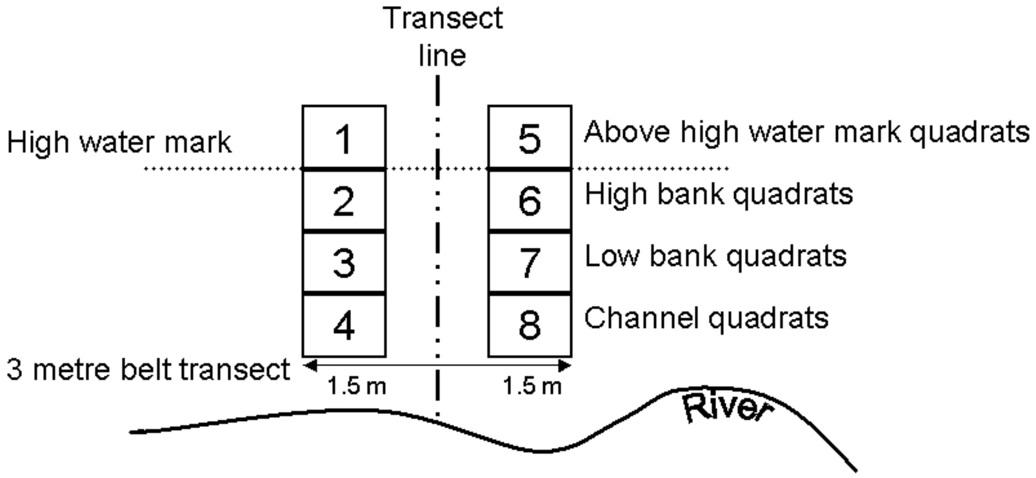


Figure 6.2. Diagrammatic representation of quadrat positions along transects in Gordon, Franklin and Denison Rivers.

Monitoring within these sites included assessment of ground species cover, seedling numbers, density of trees and shrubs, health of vegetation and habitat variables including substrate and aspect, as discussed in the following sections.

6.2.4 Data analysis

Belt transect tree data were stratified into two 3 m wide zones based on regulated water level, and standardised to provide a total density per 9 m^2 (plot) measurement. Species rooted in sections of the bank normally inundated at regulated flow levels were classified as the 'below regulated flow' area and trees rooted in the areas above this were classified as the 'above regulated flow' area. These data were analysed for different effects between 'above' and 'below' the regulated flow type.

All other data were explored for normality and where necessary, skewed distributions and outliers in the species data were corrected using a $\log_{10}$ transformation. Because $\log_{10}$ transformation converts zeros to missing values that would bias analyses, a constant value (1) was added to all data prior to transformation (Quinn and Keough 2002). Arcsine transformations proved more effective in correcting the percentage cover data for the dependent variables 'total vegetation cover' and 'total bare substrate'.

Species and ground cover data were analysed using repeated measures analysis of variance (ANOVA) to test the effect of year and zone (Quinn and Keough 2002). 'Zone' was added as a between-subjects factor in all ANOVA analyses. Polynomial contrasts were examined for significant interactions to determine the nature of any significant trends in the data, i.e. whether trends were linear, quadratic or cubic. Following analysis, residuals were plotted against estimated values for a normal distribution to ensure test assumptions were fulfilled.

6.3 Results

6.3.1 Community dynamics shown in photo-monitoring

Photo-monitoring was undertaken at 35 sites over the pre-Basslink monitoring period, allowing comparisons to be made between years. Analysis of the photographs allowed assessment of coarser-scale patterns, such as decreases or increases of abundance of strata within the vegetation. The results for the 2002 and 2003 monitoring pairs are presented in Figure 6.3.

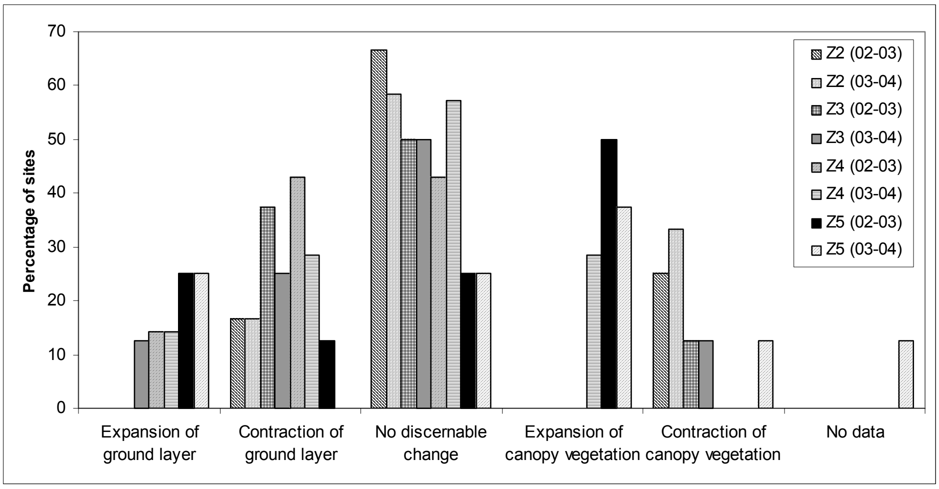


Figure 6.3 Summary of photo-monitoring results in zones 2-5 for middle Gordon River, December 2002-November 2003 and November 2003-December 2004.

Most photo-monitoring sites showed no discernable change over the monitoring period (see Figure 6.3). The dominant pattern of change over both periods of analysis was the contraction of ground layer vegetation which occurred at numerous sites in all zones. Much of this contraction was the result of dieback of ferns such as *Blechnum* spp. and grass species. However, the inverse pattern of ground cover expansion was the next most commonly recorded pattern in the photo-monitoring. This was also the result of changes in fern cover, most of which occurred in zone 5. The expansion of the canopy vegetation in zones 4 and 5 was due to thickening of existing tree canopies, largely *Pomaderris apetala*. Contraction of the canopy vegetation in zones 2-4 for this time period reflected continuing thinning of *Leptospermum riparium* shrubs and retreat of the bottom of the canopy to a higher level.

6.3.2 Species diversity and cover

6.3.2.1 Trees and large shrubs

The density of trees <5 cm and <10 cm in diameter was higher in the area above regulated flow, for most sites. Whereas, larger trees (in the <20 cm and >20 cm size classes) dominated in areas that are below regulated flows, at most sites. There were no significant differences in tree size classes between the zones. Figure 6.4 shows the total number of trees in each of the four size classes for each site, separated by location above or below the regulated flow level.

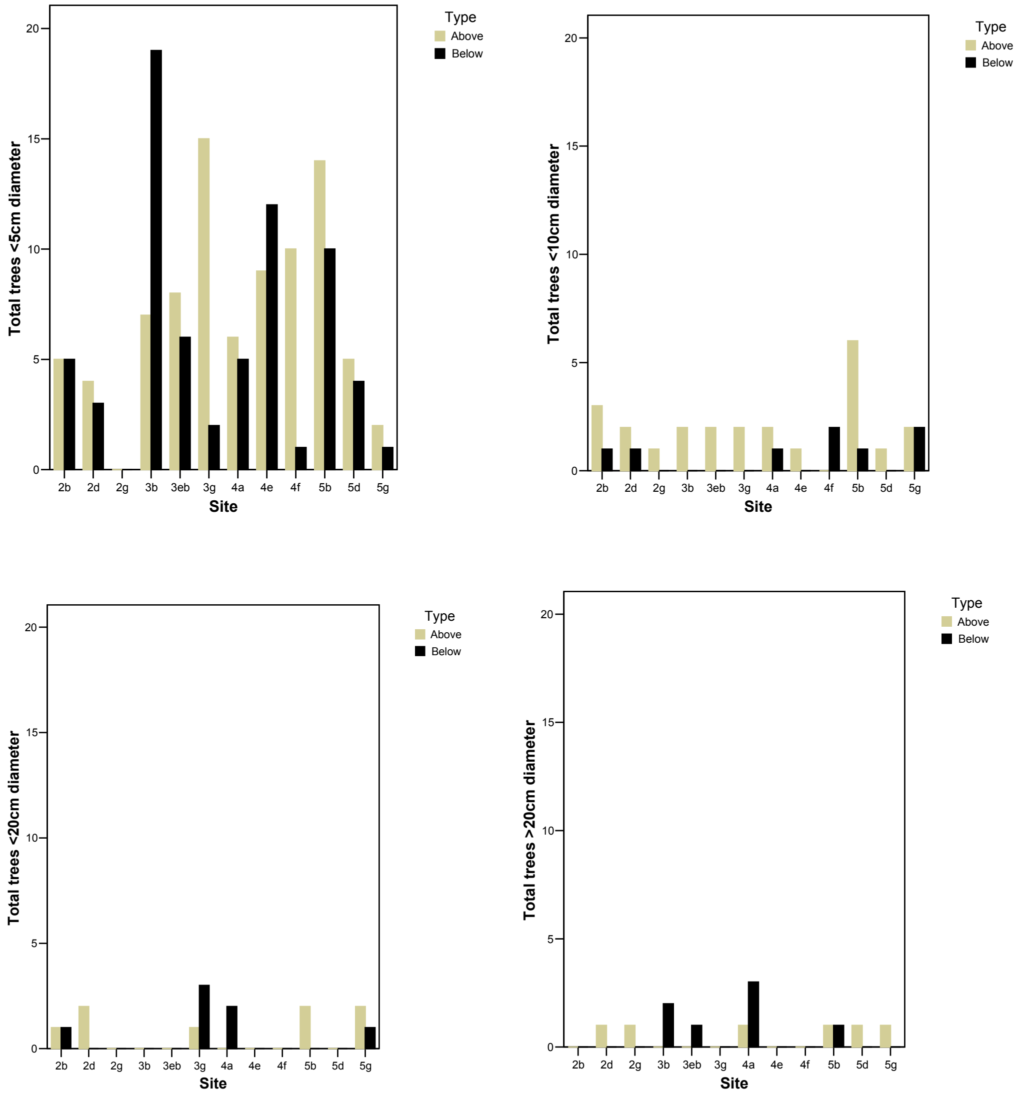


Figure 6.4 Total numbers of tree and large shrubs in four size classes in the Gordon River.

Repeated monitoring showed less than 2% tree mortality over the 2002-05 monitoring period, most of which occurred below the regulated flow level. Species included *Leptospermum riparium, Acradenia frankliniae* and *Anopterus glandulosus* in the <5 cm size class.

6.3.2.2 Bryophytes, ferns, small shrubs, graminoids, grasses and herbs

Bryophyte (moss and liverwort) cover was consistently higher than all other life forms in all quadrat types except in 2002 in the 'low' quadrats. Mean cover was higher between the 'above' quadrats compared with the 'high' quadrats and the 'high' quadrats compared with the 'low' quadrats. This present cover did not change significantly over the monitoring period from 2002 to 2005 or between zones. Mean present cover of fern and small shrub species was consistently higher in the 'above' and 'high' quadrats in grouped data (Figure 6.5) and in zones 2 to 4. Mean cover of ferns was of reduced relative importance in zone 5 for all monitoring events, with tree species and graminoids providing greater mean cover. Fern cover in the 'low' quadrats changed over the sampling period between the zones. This reflects a decrease in cover of *Blechnum* spp. in these quadrats in zones 2 and 3. Small shrub cover in the 'low' quadrats displayed an overall decline in all zones. There was a dramatic decline of shrub cover at one site in zone 4, where a minor slip had reduced the cover of *Leptospermum riparium* and *Pultenaea juniperina.*

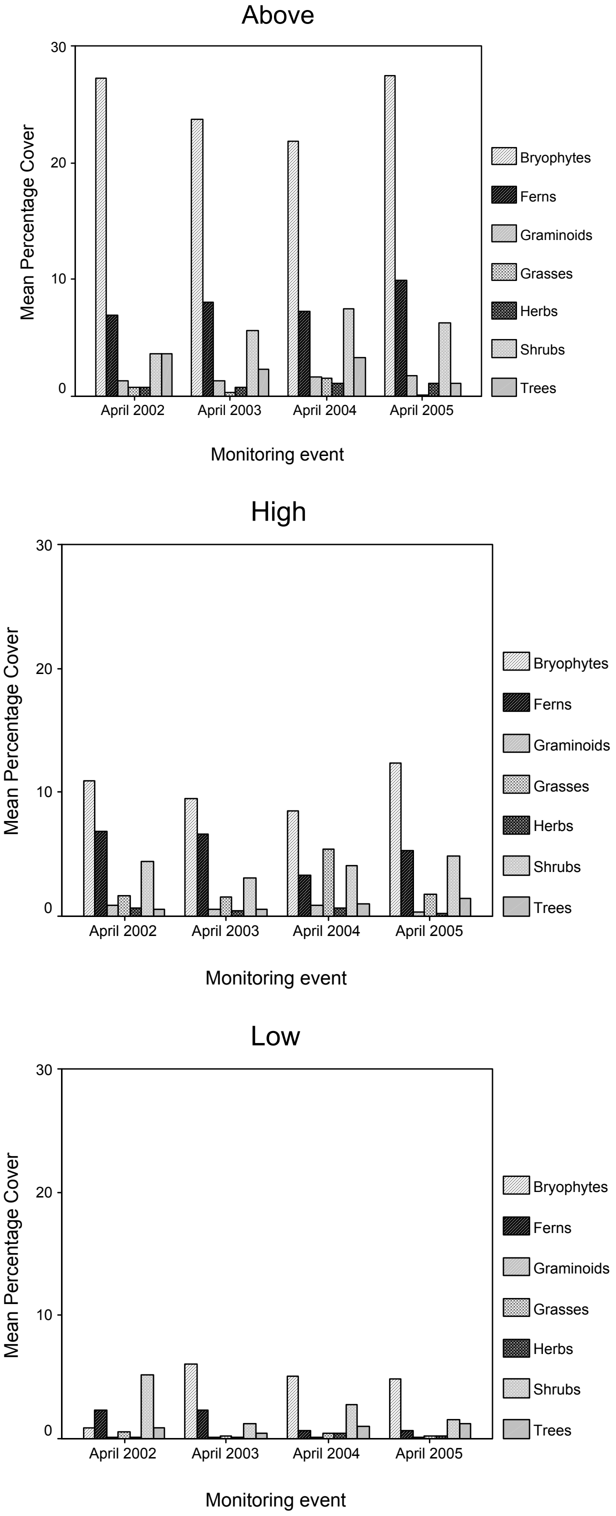


Figure 6.5 Mean percentage cover of vegetation life forms in all zones and sites by monitoring event for analysed quadrat types in the Gordon River.

The 'low' quadrats recorded greater relative importance of shrub species followed by fern species, although mean cover was very low. Graminoid species, such as sedges and lilies were almost absent from these lower quadrats. Tree cover in these quadrats was largely the result of low (<1m) overhanging branches rather than tree species rooted in the quadrats.

The other life forms: graminoids, grasses, herbs and trees had low abundance and frequency in all quadrat types. An outlying peak of grass cover in April 2004 was the result of one 'high' quadrat in zone 5 having greater than 50% cover of *Poa* species and *Ehrharta stipoides*. This increased abundance was not apparent in April 2005.

Total vegetation cover (the sum of cover of all life form data) showed changes in vegetation cover over the sampling period that differed more between the zones than over the years (see Figure 6.6). This indicates a pattern of continued decline in vegetation cover in zone 2, predominantly caused by loss of *Acradenia franklinii* tree cover at one site. Total vegetation cover in the other zones fluctuated over the years, generally decreasing in zone 3 before an increase in 2005 and increasing in zone 4 until a decrease in 2005.

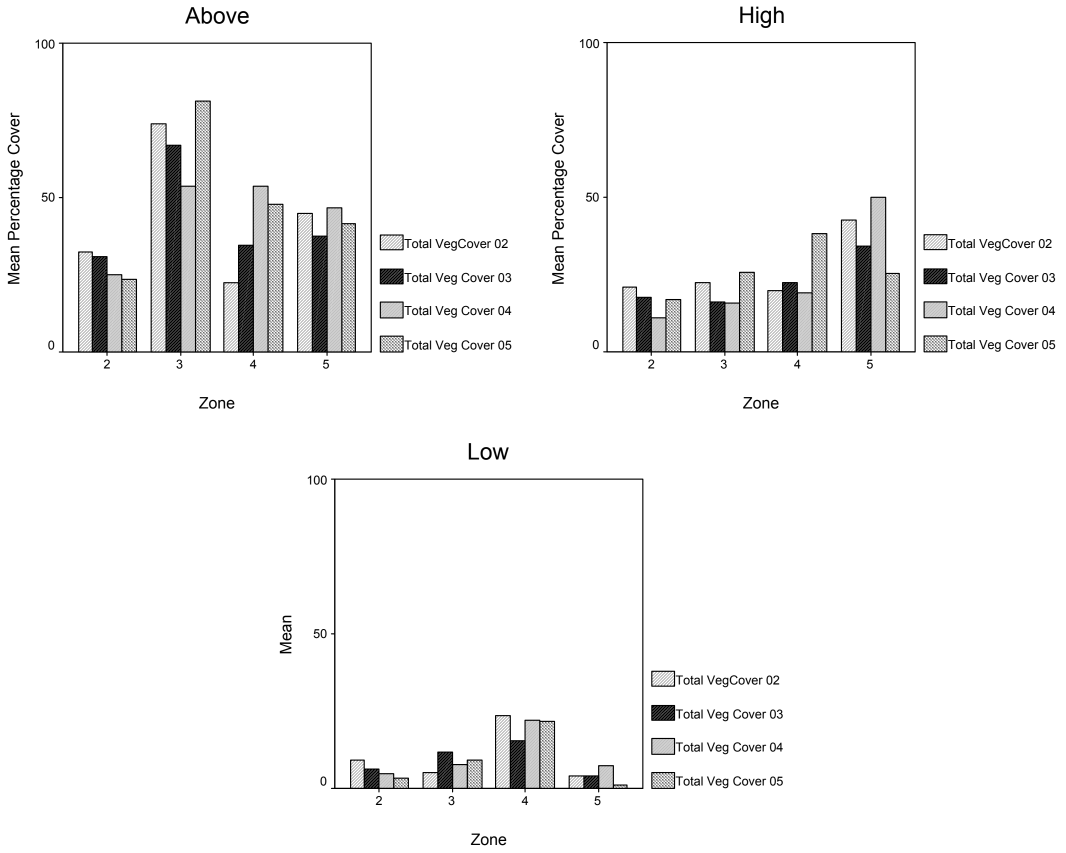


Figure 6.6 Mean percentage cover of total vegetation cover at all sites by zone for quadrat types (low, high, above) in the Gordon River.

6.3.3 Ground cover

Analysis of total bare substrate (a composite of root exposure and bare ground) showed changes in total bare substrate cover between sampling periods to differ more between the years than between the zones (Figure 6.7). However, while the differences were significant from year to year, there was no discernible pattern apparent.

Coarse woody debris changed significantly over time and between the zones. Litter also showed a significant change in the high quadrats over time and a change between zones between times in the above quadrats. Both these variables were very dynamic and strongly influenced by the flows immediately preceding the monitoring period. While the differences were significant, there was no discernible pattern apparent. This reflects the influence of floods on these variables and the differences in flood frequency and intensity between those zones influenced by natural flows (zones 4 and 5) and those largely restricted to regulated flows (zones 2 and 3).

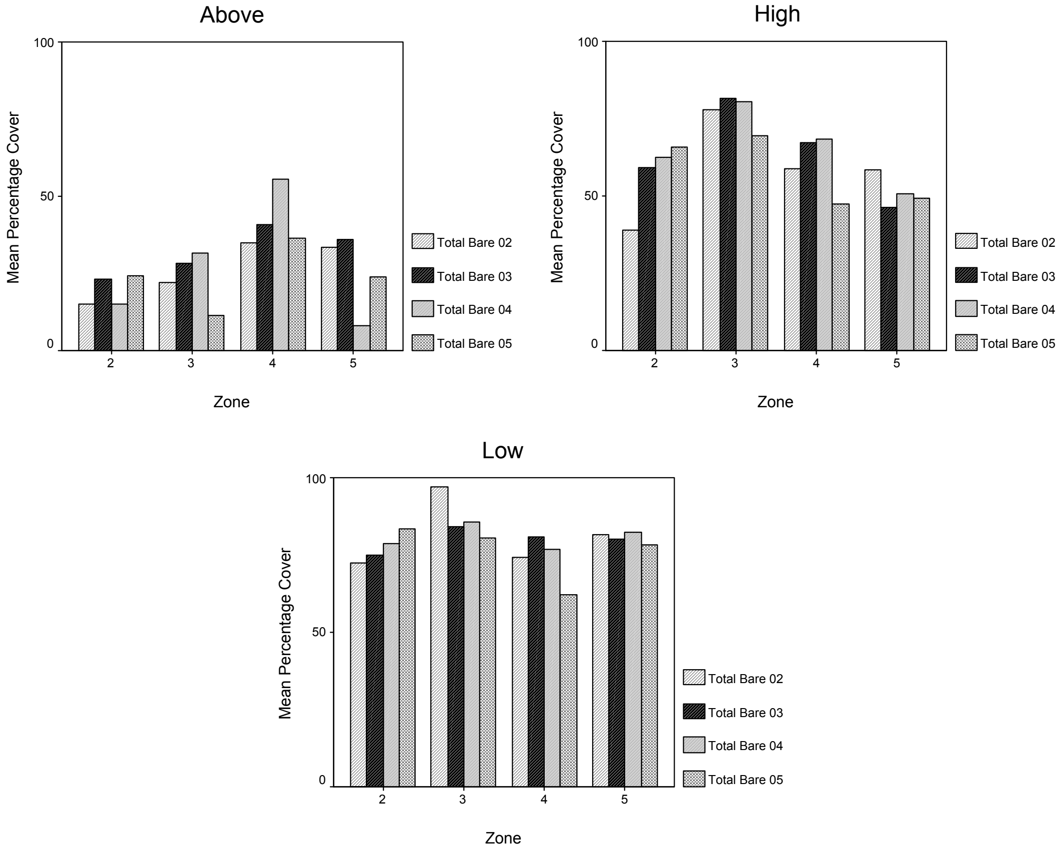


Figure 6.7. Mean percentage cover of total bare substrate at all sites by zone for quadrat types (low, high, above) in the Gordon River.

6.3.4 Seedling recruitment

Total seedling abundance over the monitoring period showed complex interactions for all quadrats with year and seasonal effects apparent (Figure 6.8). The seasonal effect is expected as seedlings peak in the summer period and subsequently die as a result of waterlogging and inundation due to flow regulation. The variation between years is likely to be a reflection of the alterations in power station operating regimes, flows and extended shut downs over the monitoring period. The following discussion highlights general trends in these data for each zone.

Zone 2 mean seedling numbers generally followed the established pattern of a peak in the summer monitoring, and reduction in the autumn, in all quadrat types. The exception to this pattern was evident in the channel quadrats in December 2004. Mean seedling numbers in all other quadrat types were higher in the December 2004, continuing a trend of increasing seedling numbers over the summer monitoring periods. However, April 2005 showed a substantial increase in the 'above' quadrats.

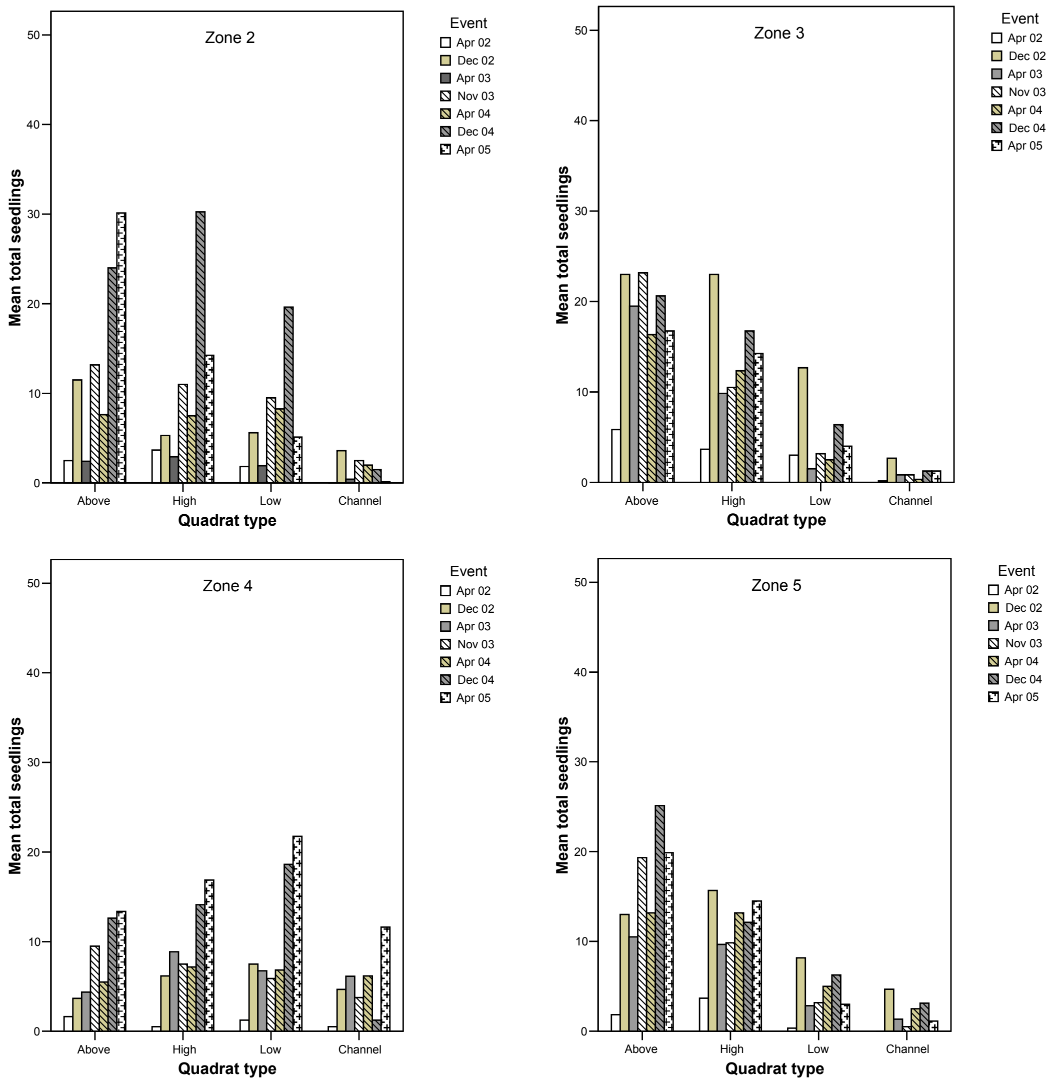


Figure 6.8. Mean number of seedlings per quadrat by quadrat type for each zone over the seven monitoring events.

The increase in mean seedling numbers in the 'above' and 'high' quadrats were the result of large numbers of *Acacia* spp., *Nothofagus cunninghamii, Leptospermum riparium* and *Anopterus glandulosus* seedlings at numerous sites. *Nothofagus cunninghamii, Anopterus glandulosus, Leptospermum riparium* and *Blechnum nudum* seedlings at two sites contributed to the high numbers in the 'low' quadrats.

The most abundant seedlings in zone 2 over the monitoring period in descending order of total abundance were:

- the tree *Nothofagus cunninghamii* (myrtle) (<5 cm);
- the small herb *Drymophila cyanocarpa* (Native Soloman's Seal) (<5 cm);
- unknown dicotyledon and monocotyledon seedlings (<5 cm).

These taxa all had a mean occurrence greater than 1 for all quadrats. *Nothofagus* were the most abundant seedlings in all quadrats, including the channel quadrats. Seedling numbers have generally been increasing throughout the pre-Basslink period, with the exception of November 2003, which showed a small decrease. *Drymophila cyanocarpa* was more abundant in the 'above' quadrats than all other quadrats (Kruskal-Wallis test $p<0.05$). This is likely to indicate that this species is not tolerant of high disturbance for germination and the period of shut down provided conditions stable enough to allow for germination in lower quadrats.

Seasonal patterns in zone 3 were not as pronounced as those displayed in zone 2. However, the stratification between the 'above' high water quadrats and the quadrats below high water flows was more pronounced. Seedling numbers in the 'above' quadrats were higher indicating a more favourable environment for establishment. When compared with quadrats at equivalent heights in other zones, the mean seedling numbers are generally much higher. The most abundant seedlings in zone 3 over the monitoring period in descending order of total abundance were:

- the trailing herb *Clematis aristata* (Clematis) (<5 cm);
- *Nothofagus cunninghamii* (myrtle) (<5 cm);
- unknown dicotyledons and monocotyledons (<5 cm) ;
- the shrub *Anopterus glandulosus* (native laurel) (<5 cm).

Clematis aristata is a trailing herb that often had high numbers of seedlings present and few adult plants. Seedlings were most abundant in the upper, less disturbed quadrats with few individuals in lower quadrats. The presence of some individuals on vertical faces in the lower channel quadrats in April 2003 after a summer of relatively high power station operation indicated that this species was tolerant of inundation and mechanical stress. Seedlings also persisted in channel quadrats in November 2003 and December 2004. The next most abundant seedling, *Nothofagus cunninghamii,* followed the quadrat stratification pattern displayed in zone 2, and the same substantial reduction in seedlings in November 2003 and increase in abundance in April 2004. *Anopterus glandulosus* is a small to medium sized shrub that is commonly found on the banks in the middle Gordon River in all life stages. The seedlings often form dense clusters on bare mineral soils in shaded environments.

The seedlings present in zone 3 also showed stratification of abundance by quadrat type with few or no seedlings present in the 'low' or 'channel' quadrats. This is indicative of a species less tolerant to disturbance. Seasonal patterns were not apparent.

Seedling abundance in zone 4 displayed almost every possible permutation of pattern over the monitoring period. Clearly this zone is more variable and the patterns between the quadrat types not as distinct. This is supported in all data collected from this zone, including the cover data for all species. This is likely to reflect the more natural flows in this zone, which receives significant inflows from the Denison River, especially in winter. The most abundant seedlings in zone 4 over the 7 monitoring events in descending order of total abundance were:

- *Nothofagus cunninghamii* (<5 cm);
- unknown dicotyledon and monocotyledon seedlings (<5 cm),;
- *Clematis aristata* (<5 cm);
- *Coprosma quadrifida* (native currant) (<5 cm)

All the major seedling species in zone 4 showed less stratification by quadrat types with higher numbers of all species being present in the 'channel' quadrats than all other zones. Again, *Nothofagus* seedlings were well represented in most monitoring events except April 2002 and November 2003. *Clematis* seedlings were recorded in most quadrat types in the later monitoring events. *Coprosma* abundance was highly variable between the seasons and the quadrat types in this zone.

Zone 5 seedling abundance showed less seasonal influence than other zones. This zone receives natural inflows from the Denison and Olga Rivers with power station discharge having only moderate, seasonal influence. The most abundant seedlings in zone 5 over the 7 monitoring events in descending order of total abundance were:

- unknown dicotyledon and monocotyledon seedlings (<5 cm);
- *Nothofagus* <5 cm;
- *Clematis aristata* (<5 cm);
- *Coprosma quadrifida* (<5 cm)

As in zones 2 and 4, *Nothofagus* seedlings were present in all quadrat types for most monitoring events as was *Coprosma.* The significant bank stabilising species *Leptospermum riparium* (tea tree) was more abundant in zone 5 compared with other zones for all monitoring periods except December 2004 when it was not recorded. This species is known to store seed in the canopy and requires large disturbance events for seedling recruitment. *Nothofagus* were the most abundant seedlings in all quadrats, including the 'channel' quadrats. Seedling numbers have generally been increasing throughout the pre-Basslink monitoring period, with the exception of November 2003.

Drymophila cyanocarpa was more abundant in the less disturbed 'above' quadrats than all other quadrats (Kruskal-Wallis test $p<0.05$). This is likely to indicate that this species is not tolerant of high disturbance for germination and the period of shut down provided conditions stable enough to allow for germination. This conclusion is supported by the dramatic decline in seedlings in the lower quadrats between November 2003 and April 2004, after resumption of normal power station operation and the low abundance of seedlings in December 2004 that did not have the same preceding shut down.

6.3.5 Identification of a threatening process in the Gordon River

There was substantial dieback of *Richea pandanifolia* (pandani) in many areas along the middle Gordon River from Abel Gorge down to the Franklin River confluence. This species is highly susceptible to the pathogen, *Phytophthora cinnamomi.* Commonly known as dieback, *Phytophthora cinnamomi* is a soil-borne pathogen, of the kingdom Chromista, which afflicts the roots of susceptible plants, starving them of nutrients and water. Long-distance spread of *Phytophthora* is principally by the transfer of infected soil or plant material by vehicles, people or animals. Dispersal of spores over short distances may occur via water movement in soil or along water courses.

Conclusive identification of a *Phytophthora* infection requires laboratory analysis of soil or root samples. Such analyses were undertaken at 14 vegetation monitoring sites along the River and at the Knob helipad. The results of these analyses showed that the disease was present at many sites in all zones along the river and is the most likely cause of dieback of *Richea pandanifolia* in many areas (Photo 6.1). However, some areas of dieback of *Richea pandanifolia* have tested negative to *Phytophthora* and localised scour and physical disturbance associated with regulated flow is more likely to have caused this dieback.

Photo 6.1. Photomonitoring in zone 3 (site 6) showing distinct dieback of Richea pandanifolia between November 2003 and December 2004.

Phytophtohra hygiene procedures have been in place since the BMP commenced. These have been updated using the most recently available information. Management strategies are being developed to determine the estent of the outbreak and reduce the risk of its further spread.

6.4 Discussion

Data collected in the 2004-05 year showed the existing vegetation to be highly stratified up the banks of the river in response to varying degrees of flow-induced disturbance. This disturbance restricts vegetation growth and recruitment in the lower channel with effects reducing in areas above flow channel disturbance or subject to shorter periods of disturbance.

The bank below the regulated water level had reduced abundance and cover of trees and shrubs in smaller size classes (<5 cm and <10 cm diameter) and ground cover species. The extant vegetation contained predominantly larger tree species (<20 cm and >20 cm diameter) that were able to resist the mechanical disturbance of high flows and were high enough to not be totally inundated thus allowing them to photosynthesize during high flows. It is this inundation of leaves, coupled with waterlogging of roots that can lead to declining carbohydrate reserves and reduced vigour, which leads to a reduction in the capacity of plants to tolerate stress, resulting in mortality. Whilst leaf inundation effects respond immediately to the on-off cycles of power station operation, waterlogging impacts can persist for longer periods. The degree and persistence of bank saturation, and hence potential for anoxic conditions around plant roots, will depend on the substrate, the period of inundation, and the height of the 'natural' groundwater levels. Peizometer measurements along banks 10 m from the river in an alluvial sand profile revealed bank draining ranged from 4 to 12 hours with an average of 8 hours (Koehnken *et al.* 2001). The period required for bank drainage is likely to be longer for banks comprising of finer sediments (Davidson and Gibbons 2001). The severity of inundation and waterlogging were also highly variable depending on the species affected.

Few species are able to tolerate long periods of inundation and waterlogging under the current regulated flow as indicated by the low species richness recorded. This has resulted in a greater relative importance of *Leptospermum riparium,* a species that is morphologically adapted to cope with inundation and waterlogging. However, photo-monitoring has show that this species is also showing signs of decline with reduced canopy extent and cover apparent. The leaves on many plants are dying back resulting in a contraction of the canopy from the bottom, indicating a stress response to increased inundation of leaves at a higher level.

The only other life form that is persistent on the bank below the regulated water level is ferns. These too showed significant decline over the monitoring period. Other life forms such as grasses, herbs and graminoids had only limited cover in these quadrats. Grouped vegetation cover data and the total bare substrate data do not show any significant trends in the banks below the regulated flow level.

The banks above the regulated water level had increased abundance of tree and shrub species in smaller size classes (<5 cm and <10 cm diameter) and ground cover species. Species richness is higher than that below regulated flow levels and most life forms are well represented. Total vegetation cover fluctuated significantly between the zones and the years. This response is likely to reflect the dynamic changes in erosion rates and substrate changes as described in the Fluvial Geomorphology section (section 4). This is also reflected in the complex interactions in the percentage cover of total bare substrate in the 'above' quadrats. The differences in abundance and cover of vegetation between the bank above and below flow regulation are a product not only of disturbance removing vegetation but also of changes to the natural processes of seedling recruitment and persistence.

Seedling recruitment and persistence along the river is primarily influenced by location on the bank in the higher zones and seasonal effects. The relative influence of bank stratification and season decreases further away from the Gordon Dam. The reduced influence of season in the downstream zones is the result of unregulated tributary on-flows that allow the more natural pulses of seedling recruitment to occur. Episodic or 'pulse' germination of seedlings is common in most environments because the conditions that favour germination are limited in time and space and often require a form of disturbance. The main agent of disturbance in riparian systems is flood, which is largely absent in the upstream zones of the Gordon River. The increased inflows and incidence of flood events in zones 4 and 5 create more opportunities for seedling recruitment on the banks.

The lack of seedling recruitment in all zones can largely be attributed to the unstable substrate of the banks. Both erosion and deposition of sediments can hinder seedling establishment. Coupled with few periods free of inundation, cooler temperatures due to substantial shading and an often saturated oxygen and deprived substrate, a low recruitment rate can be expected. However, despite the findings of other studies (see Andersson *et al.* 2000) seed availability is not likely to be limiting seedling recruitment.

Size class analysis of seedling recruitment showed that while germination does occur in most areas, including the highly impacted areas below the Plimsoll line, seedlings do not persist. Periodic waterlogging, inundation and localised scour and mechanical disturbance prove too frequent or intense to allow continued growth. This pattern is less severe, but still apparent at the last site which is 32km downstream of the tailrace.

7 Macroinvertebrates

7.1 Introduction

Macroinvertebrate monitoring was conducted in spring (October) 2004 and autumn (April) 2005 Both quantitative (surber) and rapid bioassessment (RBA) sampling was conducted at 9 sites in the Gordon River between the power station and the Franklin River junction. Sampling was also conducted at 6 reference sites in rivers within the Gordon catchment.

The locations of the monitoring and reference sites are shown in Figure 7.1.

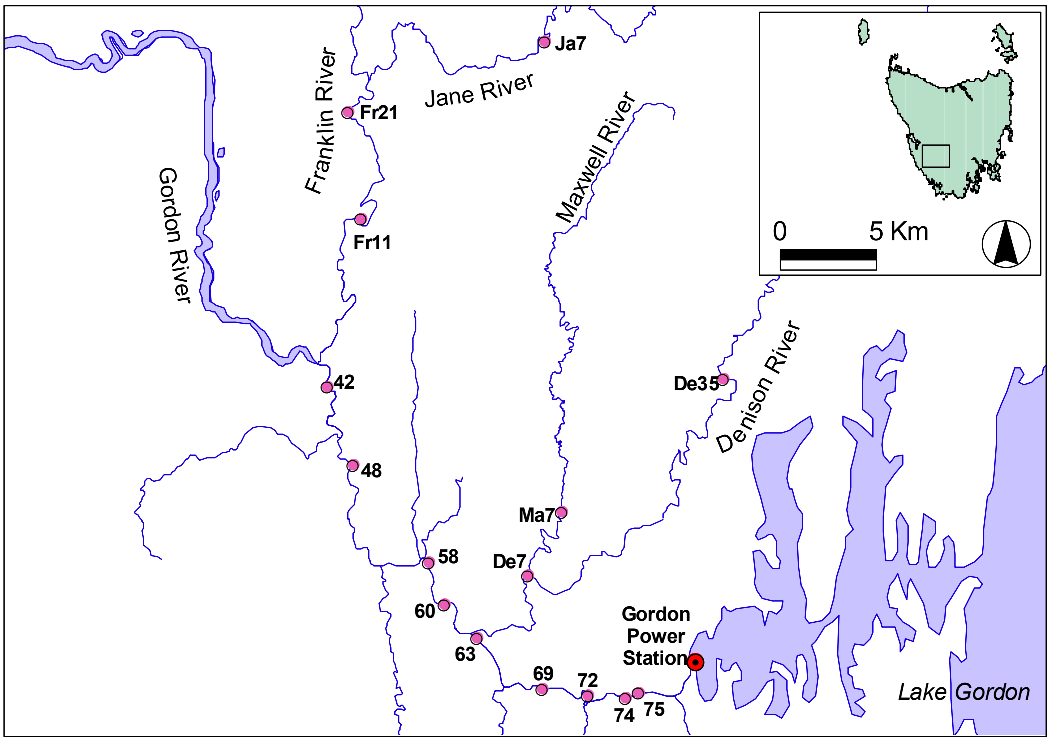


Figure 7.1. Map of the locations of macroinvertebrate monitoring sites in the Gordon, Denison and Franklin Rivers.

7.2 Methods

7.2.1 Sample sites

All 15 sites were sampled in October 2004 and April 2005. Table 7.1 gives the locations of the sampling sites.

Table 7.1. Macroinvertebrate monitoring sites sampled in October 2004 and April 2005.

River	Site name	Site code	Distance from power station (km)
Gordon	Gordon R d/s Albert Gorge (G4)	75	2
	Gordon R d/s Piguenit R (G4A)	74	3
	Gordon R in Albert Gorge (G5)	72	5
	Gordon R u/s Second Split (G6)	69	8
	(Gordon R u/s Denison R (G7)	63	14
	Gordon R d/s Denison R (G9)	60	17
	Gordon R u/s Smith R (G10)	57	20
	Gordon R d/s Olga R (G11A)	48	29
	Gordon R @ Devil's Teapot (G15)	42	35
Franklin	Franklin R d/s Blackman's bend (G19)	Fr11	-
	Franklin R @ Flat Is (G20)	Fr21	-
Denison	Denison d/s Maxwell R (G21)	De7	-
	Denison R u/s Truchanas Reserve (D1)	De35	-
Jane	Jane R (J1)	Ja7	-
Maxwell	Maxwell R (M1)	Ma7	-

7.2.2 Macroinvertebrate monitoring

The same sampling method was conducted at all sites. At each site at low flows, riffle habitat was selected and sampled by:

- Quantitative analysis: collecting 10 surber samples (30 x 30 cm area, 500 micron mesh) by hand disturbance of substrate to a depth of 10 cm and washing into the net; and
- Rapid biological assessment (RBA): disturbing the substrate by foot and hand immediately upstream of a standard 250 micron kick net over a distance of 10 m.

All surber samples from a site were pooled and preserved (10% formalin) prior to lab processing. Samples were elutriated with a saturated calcium chloride solution and then sub-sampled to 20% using a Marchant box subsampler and random cell selection. The subsamples were then hand picked and all fauna identified to family level with the exception of oligochaetes, Turbellaria, Hydrozoa, Hirudinea, Hydracarina, Copepoda and Tardigrada. Chironomids were identified to sub-family. For the autumn 2005 monitoring, identification to genus and species level was conducted for Ephemeroptera, Plecoptera, Trichoptera and Coleoptera (EPTC fauna).

Two RBA samples were collected at each site. All RBA samples were live-picked on site for 30 minutes, with pickers attempting to maximise the number of taxa recovered. All taxa were identified to the same taxonomic levels as described above.

7.2.3 Habitat variables

A set of standard physical habitat variables were recorded at each site and a number of variables were recorded from maps.

7.2.4 Analysis

O/E scores and summary trends were derived from the RBA data using the combined-season Hydro RIVPACS models developed by Davies *et al.* (1999).

O/Epa and O/Erk values were derived using the RBA macroinvertebrate data in combination with key 'predictor' habitat variables. O/Epa is derived using presence/absence data and models derived from presence/absence reference site data. O/Erk is derived using rank abundance category data and models derived from rank abundance category reference data.

Data from the RBA samples were also analysed using the single-season (autumn and spring) Hydro RIVPACS models developed for this project from the original reference site data sets used to develop the combined season models (see Davies *et al.* 1999).

7.3 Results

7.3.1 Quantitative (surber) sampling

Macoinvertebrate abundance data identified to the family level for spring (October 2004) are shown in Table 7.2 and results were comparable with previous years. The autumn (April 2005) data has been further identified to family (

Table 7.3) and EPTC species level for the first time (Table 7.4). Autumn sampling results showed that diversity and abundance were generally higher downstream of the Denison confluence, with the exception of site 60 (G9) which had a particularly low diversity. Very low flows prevented sampling at the normal location at site 60 and it is possible that the shift in sampling location may have led to a reduced diversity sample for this site. The mean annual data revealed high values for diversity and total abundance at site 72 (G5) relative to sites 75 (G4), 74 (G4a) and 69 (G6) (refer to Figure 7.2). In addition, abundance was high in the vicinity of the Denison confluence (sites 63, 60 and 57) due to elevated abundances of hydropsychids, simuliids and oligochaetes.

The abundance, diversity and composition of the EPTC taxa strongly discriminated Gordon River sites from reference sites (Table 7.4). Diversity and abundance of EPTC species were statistically lower for all Gordon River sites than for the reference sites (by t-test - both $p < 0.001$, $t > 4.5$, df = 12). Mean species richness for reference sites (mean = 17.5) was 2.3 times higher than for all Gordon River sites (mean = 7.5). Similarly, mean total abundance of reference sites (239.5 individuals/ 0.18 m^2) was 6.5 times higher than Gordon River sites (36.5 individuals/ 0.18 m^2). Gordon River EPTC taxa were dominated by *Nousia* spp. AV5/6, *Asmicridea* spp. AV1 and *Austrolimnius* larvae. Reference sites were also dominated by these taxa, as well as *Baetid* Genus 2 MV spp. 3. However, abundances of mayflies, caddis and riffle beetles at reference sites were much greater than for Gordon River sites.

Table 7.2. Macroinvertebrate abundance data (abundances as n per 0.18 m^2) for Gordon and reference sites sampled in spring (October) 2004.

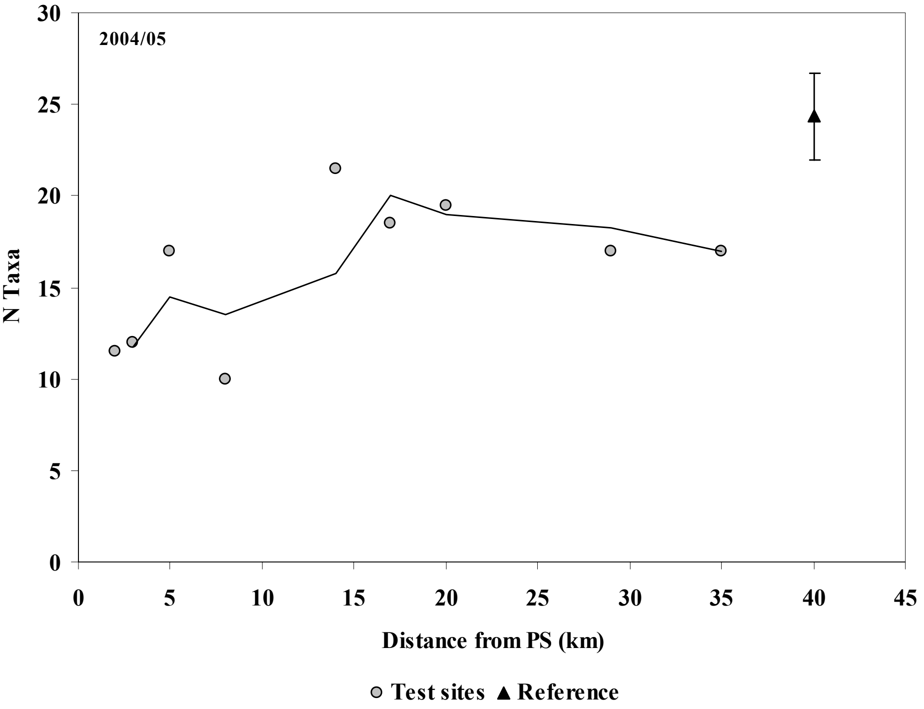
		River	Gordon									Franklin		Denison		Maxwell	Jane
Class	**Order**	**Family** Site	75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Platyhelminthes	Turbellaria		1	1	0	0	2	2	0	1	0	7	3	0	0	2	1
Nematoda			0	1	0	0	0	3	1	0	5	0	0	0	0	2	8
Mollusca	Bivalvia	Sphaeriidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Gastropoda	Hydrobiidae	0	0	0	0	1	0	4	0	4	17	2	4	0	8	0
		Ancylidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Oligochaeta		1	5	52	8	8	39	43	44	21	60	73	14	22	53	117
Arachnida	Acarina		0	0	0	0	0	0	0	0	0	0	1	0	1	0	1
Crustacea	Amphipoda	Paramelitidae	0	0	0	0	0	4	20	1	0	0	0	1	0	0	0
		Neoniphargidae	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0
	Isopoda	Phreatoicidea	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		Janiridae	15	17	7	0	1	0	0	0	0	15	2	0	0	0	5
	Plecoptera	Eustheniidae	1	0	0	0	1	0	0	0	0	3	0	2	0	1	1
		Austroperlidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Gripopterygidae	0	1	121	1	48	27	34	4	10	17	7	9	5	32	29
		Notonemouridae	0	0	2	0	0	1	0	0	1	0	0	0	0	0	0
	Ephemeroptera	Leptophlebiidae	0	0	19	0	7	53	16	10	23	70	62	82	112	70	156
		Baetidae	0	0	0	0	0	0	1	0	0	4	2	3	3	31	9
		Saldidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Diptera	Chironomidae: Chironominae	0	3	6	0	4	4	10	4	50	6	7	4	1	1	2
		Chironomidae: Orthocladiinae	5	0	21	1	10	5	10	0	0	5	4	1	2	6	2
		Chironomidae: Podonominae	0	0	5	1	0	5	0	3	3	3	5	7	1	12	6
		Chironomidae: Diamesinae	7	8	3	2	0	0	0	0	0	0	0	0	0	0	0
		Chironomidae: Aphroteniinae	0	0	0	0	0	0	0	0	0	0	2	1	1	0	1
		Simuliidae	0	1	7	0	5	115	47	65	26	291	174	88	26	15	69
		Tipulidae	0	0	1	0	1	1	3	0	1	0	0	0	0	0	0
		Athericidae	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
		Blephariceridae	0	1	0	0	0	3	0	6	7	45	38	10	2	3	4
		Ceratopogonidae	0	0	0	0	0	0	0	0	0	4	9	0	0	0	0
		Empididae	0	0	0	0	1	1	1	0	1	0	0	0	1	6	1
		Dip. Unid. Pup.	1	0	6	0	1	7	5	1	19	1	4	11	1	0	0
		Calocidae	0	0	0	0	0	2	0	0	0	0	0	0	0	1	5
		Conoesucidae	0	0	2	0	10	10	12	1	4	8	1	1	2	35	7
		Glossosomatidae	0	0	0	0	0	0	0	0	0	13	0	0	0	3	2
		Helicophidae	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
		Helicopsychidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Hydrobiosidae	3	0	2	0	3	5	3	3	1	17	3	2	2	3	3
		Hydropsychidae	0	0	0	0	397	249	280	5	11	6	1	1	3	8	1
		Hydroptilidae	0	0	7	0	11	1	1	0	0	0	0	0	0	0	0
		Leptoceridae	0	0	0	0	2	1	0	0	0	2	4	4	4	4	2
		Philopotamidae	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
		Philorheithridae	0	0	0	0	0	1	0	0	1	1	0	1	2	3	4
		Trich. Unid. Pup.	0	0	0	0	0	1	1	0	2	1	0	0	0	2	0
	Coleoptera	ElmidaeA	0	0	3	0	9	4	17	1	1	44	22	28	75	62	112
		ElmidaeL	0	0	5	1	3	12	6	1	3	68	38	58	119	79	185
		ScirtidaeL	0	0	0	0	0	0	0	1	2	1	4	3	0	5	0
		PsephenidaeL	0	0	0	0	0	0	0	0	0	3	0	1	1	10	1
		N Taxa	**9**	**9**	**18**	**6**	**22**	**26**	**21**	**17**	**22**	**26**	**24**	**23**	**23**	**29**	**27**
		Total abundance	**35**	**38**	**270**	**14**	**527**	**558**	**516**	**152**	**197**	**712**	**469**	**336**	**388**	**461**	**735**

Table 7.3. Macroinvertebrate abundance data at the family level (abundances as n per 0.18 m^2) for Gordon River and reference sites sampled in Autumn (April) 2005.

		River:	**Gordon R**									**Franklin R**		**Denison R**		**Maxwell R**	**Jane R**
		Site:	75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Class	**Order**	**Family**	G4	G4a	G5	G6	G7	G9	G10	G11B	G15						
Cnidaria	Hydrozoa			1	1	4	1										
Platyhelminthes	Turbellaria						2		2							4	
Nematoda									4	1						1	
Mollusca	Bivalvia	Sphaeriidae					1			1							
	Gastropoda	Hydrobiidae		1		1	1	1	7	4	2		1	2		3	
		Ancylidae											12			1	
		Glacidorbidae					1										
Annelida	Oligochaeta		5	8	29	3	15	51	222	93	45	10	17	25	37	49	69
Arachnida	Acarina												2		1	2	
Crustacea	Amphipoda	Paramelitidae		1					1	1	1			3		2	
		Neoniphargidae	1		1	1											
	Isopoda	Phreatoicidea				2											
		Janiridae	14	8	7	2	1			1		1	23				
		Oniscidae			1												
Insecta	Plecoptera	Eustheniidae		1		1							1	1		1	
		Austroperlidae				1											
		Gripopterygidae	1	4	7		8	1	2	2	3		4	9	5	2	6
	Ephemeroptera	Leptophlebiidae	3		4	4	5		1	7	12	61	17	42	40	65	37
		Baetidae	1						2			5	35	8	21	55	45
	Hemiptera	Veliidae											1				
	Diptera	Chironomidae:Chironominae		1	1	2	1		9			2		8	2	1	1
		Chironomidae:Orthocladiinae	3	5	20	5		6	3			12	13	4	10	5	4
		Chironomidae:Podonominae	1									11			3	2	4
		Simuliidae	3	12	17	1	37	95	77	83	80	203	27	60	141	16	62
		Tipulidae			1				1	2						1	1
		Blephariceridae						1		4	3	6	1	2	9		
		Chaoboridae			1		3										
		Empididae		1			4	1	2				2	1	1	4	1
		Dip. Unid. Pup.					2	1			3	29	9	13	1	2	
	Trichoptera	Calocidae								2		1	2	2	1	2	5
		Conoesucidae	1	3	2		3	1	2				12	1	2	12	21
		Glossosomatidae	1				1					2	3	1			27
		Hydrobiosidae		3	2		8				1	8	5	3	5	8	7
		Hydropsychidae	3	2	1	1	137	4	23	1	7	1	17	8	22	36	37
		Leptoceridae	1	1						2	1	8	5	6	7	20	1
		Philorheithridae							1	1		3	3	2	3	6	
		Trich. Unid. Pup.					3						1				2
	Coleoptera	ElmidaeA					2		2		1	9	14	43	22	55	79
		ElmidaeL	9		1		3	2	13	3		37	49	78	51	81	143
		ScirtidaeL				2				1		40	25	36	27	53	56
		PsephenidaeL											2	1		1	1
		Total abundance	**47**	**52**	**96**	**30**	**239**	**164**	**374**	**209**	**159**	**449**	**303**	**359**	**411**	**490**	**609**
		N Taxa	**14**	**15**	**16**	**14**	**21**	**11**	**18**	**17**	**12**	**19**	**27**	**24**	**21**	**28**	**21**

Table 7.4. Quantitative macroinvertebrate data for EPTC taxa -Ephemeroptera, Plecoptera and Trichoptera and Coleoptera (abundances as n per 0.18 m^2) for Gordon and reference sites.

		River :	**Gordon R**									**Franklin R**		**Denison R**		**Maxwell R**	**Jane R**
		Site :	75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Order	**Family**	**Genus/species**	G4	G4a	G5	G6	G7	G9	G10	G11B	G15						
Ephemeroptera	Baetidae	Baetid Genus 2 MV sp 3							2			5	35	8	21	55	45
	Leptophlebiidae	Austrophlebioides sp AV7													2		
		Nousia sp AV5/6	1		3	4	5		1	5	11	61	16	42	37	62	37
		Nousia sp AV7	1		1					1					1		
		Nousia sp AV8											1				
		Nousia sp AV9														3	
		Tillyardophlebia sp AV2								1							
Plecoptera	Eustheniidae	Eusthenia spectabilis		1									1	1		1	
	Austroperlidae	Tasmanoperla thalia	1			2											
	Gripopterygidae	Cardioperla media/lobata			2		1			1	1			1		1	
		Cardioperla spinosa							1							1	
		Dinotoperla serricauda															1
		Trinotoperla tasmanica					3							1			
		Trinotoperla zwicki	1	4	4		4	1	1	1	3			7	5		5
	Notonemouridae	Austrocercoides sp			1												
Trichoptera	Calocidae	Tamasia variegata								2		1	2	2	1	2	5
	Conoesucidae	Conoesucus brontensis											1		2		
		Conoesucus nepotulus		2			3	1	2				11			10	20
		Conoesucus sp AV7												1			
		Costora delora		1													1
		Lingora aurata														2	
	Glossosomatidae	Agapetus sp AV1	2				1					2	3	1			27
	Hydrobiosidae	Apsilochorema obliquum				1											
		Moruya opora													1		
		Taschorema complex		1	2		8				1	4	5	2	3	8	7
		Ulmerochorema rubiconum			1							4		1			
		Ulmerochorema rubiconum grp		2											1		
	Hydropsychidae	Asmicridea sp AV1		2	1		136	4	23	1	2	1	17	8	20	34	37
		Smicrophylax sp AV3	1				1								2	2	
	Leptoceridae	Notalina fulva														1	
		Notalina sp AV8		1						2		8	5	6	6	19	1
		Triplectides proximus													1		
		Tasmanthrus sp							1	1		3	3	2	3	6	
Coleoptera	Elmidae	Austrolimnius sp adult					2		2			9	11	43	20	46	78
		Austrolimnius sp larvae	6				3	2	12	3	2	37	46	77	51	70	142
		Kingolus sp adult											2		2	8	
		Simsonia sp adult											1				1
		Kingolus flavoplagiatus														2	
		Kingolus aeratus											1	1		1	
		Notriolus sp adult														1	
		Simsonia leai	1						1				2			8	1
	Psephenidae	Sclerocyphon secretus											2	1		1	1
		Total abundance	**14**	**14**	**15**	**7**	**167**	**8**	**46**	**18**	**20**	**135**	**165**	**205**	**179**	**344**	**409**
		N Species	**8**	**8**	**8**	**3**	**11**	**4**	**10**	**10**	**6**	**11**	**19**	**18**	**18**	**23**	**16**



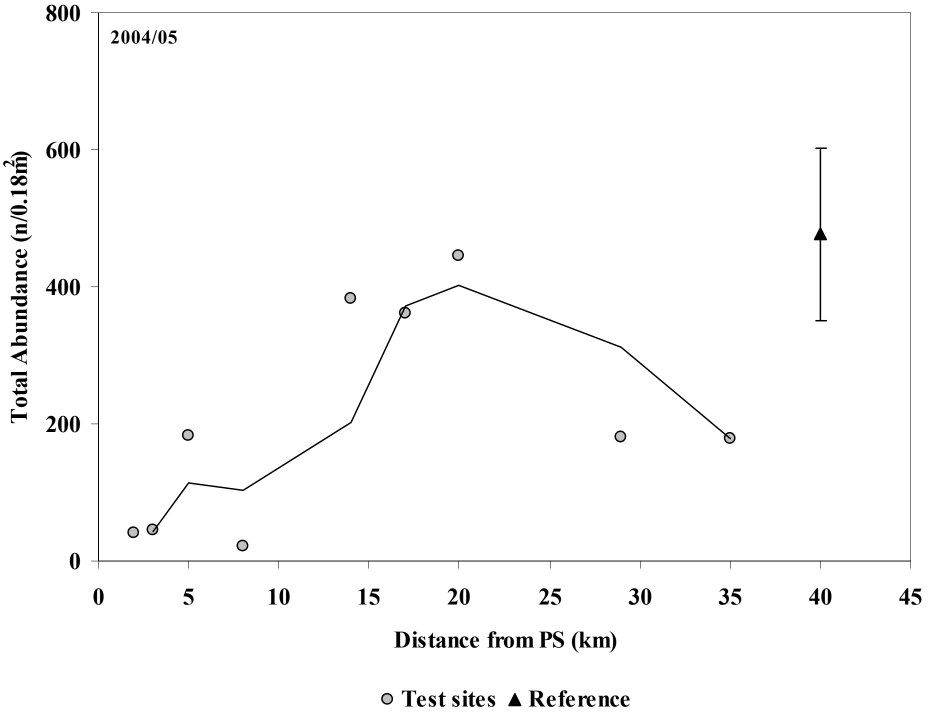


Figure 7.2. Trends in mean diversity (number of taxa) and total abundance of macroinvertebrates at sites in the Gordon River in 2004-05 with distance downstream of the Gordon Power Station. Mean values for the combined reference sites sampled at the same time are also shown, with error bars (+/- 1 SD).

7.3.2 RBA (kick) sampling

7.3.2.1 Combined season model analysis

Macroinvertebrate abundance data obtained from RBA sampling for spring (October 2004) and autumn (April 2005) are shown in Table 7.5 and Table 7.6, respectively. Note that the autumn data has one replicate missing for site 63 (G7) and one replicate which fell outside the normal criteria for sample performance for site 48 (rep. 1). These samples were not included in the RIVPAC analysis.

The RBA data were entered, along with values of predictor variables into the combined season RIVPACS models developed by Davies *et al.* (1999). O/E values derived from the presence/absence (O/Epa) and rank abundance (O/Erk) models are shown in Table 7.7. The changes in O/E values with distance downstream of the power station and at the reference sites are shown in Figure 7.3. Overall, the values of O/E and the downstream trends are similar to those observed previously in 1995-96, 1998-99 by Davies *et al.* (1999), Davies and Cook (2001) and in the Gordon River Basslink Monitoring Annual Reports from 2001-02 to 2003-04.

The O/Erk values for site 60 were lower than expected, possibly reflecting the change to a sub-optimal sampling location due to very low flows. As in previous years, O/Epa and O/Erk values upstream of the Denison River fall into the significantly (B) to severely impaired (C) bands, while sites downstream of the Denison River fall around the lower margin of band A, and were statistically significantly lower than for reference sites (both $p < 0.05$ by *t*-test). Thus, O/E values were low in the Gordon River reach upstream of the Denison confluence, with values increasing downstream of the Denison River but still falling below those observed for reference sites. An exception was site 60, which was in bands A and B for O/Epa and O/Erk models, respectively.

Table 7.5. RBA macroinvertebrate data (abundance per live picked sample) for Gordon River and reference sites sampld in spring (October) 2004. (1) and (2) denote replicate samples taken at each site.

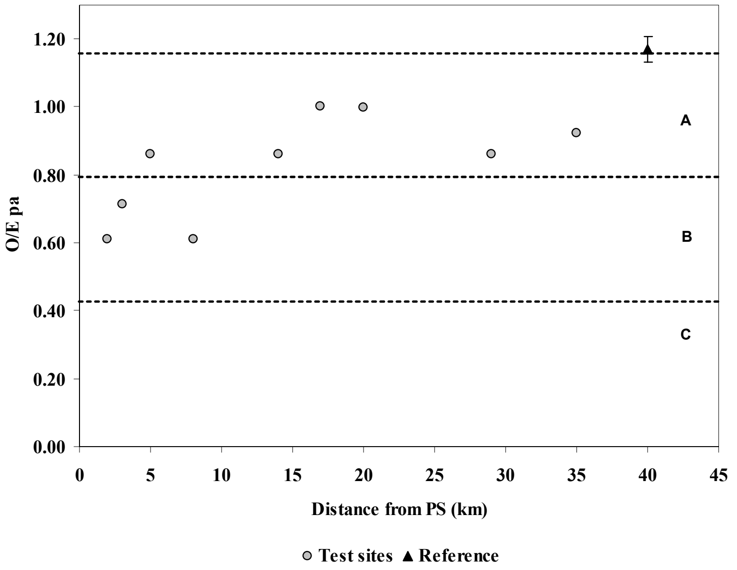
		River:	Gordon																		Franklin		Franklin		Denison		Denison		Maxwell		Jane	
		Site:	75		74		75		69		63		60		57		48		42		Fr11		Fr21		De7		De35		Ma7		Ja7	
Class	**Order**	**Family**	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Platyhelminthes	Turbellaria			3						1	1													2						1		
Nematoda																											1			2		
Mollusca	Gastropoda	Hydrobiidae									1					2					1	1								2		5
		Planorbidae	1																													
Annelida	Oligochaeta		3	2	15	7	11	5		19	11	10	6	3	8	17	27	27	18	13	4	12	4	6	2	3	8	19	6	9	6	9
Arachnida	Acarina													1							2		3	3		1			4	18	2	6
Crustacea	Amphipoda	Paramelitidae	5	27	5	1				1	2				20	6	1	1	1	1					1	1			1			1
		Ceinidae																1														
	Isopoda	Phreatoicidea							1																							
		Janiridae	7	50	3	1																1	1									
Insecta	Plecoptera	Eustheniidae	3	1	5		3	2	1				1	3		1	3	1	6	10	3		5	4	1		1	2	1	1	1	2
		Austroperlidae	1		7	3																1										
		Gripopterygidae		1	6	6	92	112	3	22	22	18	14	30	19	22	12	15	14	7	19	15	16	9	32	23	10	4	40	24	20	38
		Notonemouridae		5			1		6	1	2	3						1														
	Ephemeroptera	Leptophlebiidae	7	7	9	3	41	37	6	8	14	21	98	130	110	80	76	68	79	50	80	84	74	99	117	80	87	158	84	58	81	84
		Baetidae											1	2	1	1	1	3	1		8	8	5	10	4	7	3	2	26	6	16	6
	Diptera	Chironomidae: Chironominae	1		2					1	1			1	2		2	2	1	6	2		1		1	1				2	1	1
		Chironomidae: Orthocladiinae	12	1	5	2	11	6		1	5						3	1			2	1	3	1	1				3	6		1
		Chironomidae: Podonominae	3	4	2	4	8	7		3			11	14	16	17	38	37	3	3	10	8	8	8	12	9	13	3	14	7	18	19
		Chironomidae: Diamesinae	35	16	1	2	5	5															1		1							
		Simuliidae			4	2	4	4	1	6	1	3	20	35	15	21	57	47	9	7	22	30	29	39	27	41	9	14	8	3	4	11
		Tipulidae					2	2		1	1			1	3					1	2		1		1	1	1	4	2			1
		Athericidae							1																							1
		Blephariceridae			2									2	1		12	5	7	3	6	4	22	15	8	6						
		Empididae				1	1									2																
	Trichoptera	Calocidae															1															2
		Conoesucidae					6	2			2		2			1	1	2	2		28	4	3	3	1	2			8	16	17	17
		Glossosomatidae													5				2		6	1							6	2		12
		Helicophidae																			2											
		Hydrobiosidae	7	1	8	10	9	12		13	12	11	13	29	20	16	15	23	9	9	16	21	22	19	32	28	15	24	28	6	13	39
		Hydropsychidae									75	111	31	32	11	15	1	4	2							1			3	5	7	4
		Hydroptilidae					3																									
		Leptoceridae			1	1		1					1		1	1							1	2	1	1		3				
		Philopotamidae					2																									
		Philorheithridae													2	2		1	1		4	5	2	4	2	4		4	1	1	2	4
		Trich. Unid. Pup.									2		1	5			2	1		2		1	3		1				7	3		
	Coleoptera	ElmidaeA				1	3			1	3	5	8	3	8	6	4	3	6		19	27	19	29	21	46	16	30	31	51	22	38
		DytiscidaeA																										1				
		ElmidaeL											2		1			1			3	1	4	11	5	5	2	8	1	2	6	7
		ScirtidaeL		1						1			1					1		1					1	1				1		
		PsephenidaeL				1	1								1						2	1	3	4	3	3	1		3			2
		N Taxa	**12**	**13**	**15**	**15**	**17**	**12**	**7**	**14**	**16**	**8**	**15**	**15**	**18**	**16**	**17**	**21**	**16**	**13**	**21**	**19**	**22**	**18**	**22**	**20**	**13**	**14**	**20**	**22**	**15**	**23**
		Total abundance	**85**	**119**	**75**	**45**	**203**	**195**	**19**	**79**	**155**	**182**	**210**	**291**	**244**	**210**	**256**	**245**	**161**	**113**	**241**	**226**	**230**	**268**	**275**	**264**	**167**	**276**	**277**	**226**	**216**	**310**

Table 7.6. RBA macroinvertebrate data (abundances per live picked sample) for Gordon River and reference sites sampled in autumn (April) 2005. * denote lost sample replicate.

Date:	**2/04/2005**	**River :**	**Gordon R**																		**Franklin R**				**Denison R**				**Maxwell R**		**Jane R**	
		Site :	**75**		**74**		**72**		**69**		**63**		**60**		**57**		**42**		**48**		**Fr11**		**Fr21**		**De7**		**De35**		**Ma7**		**Ja7**	
Class	**Order**	**Family**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2***	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Cnidaria	Hydrozoa					2	1																									
Platyhelminthes	Turbellaria		21	25												1	3	4			1				1				1			
Nematoda								1																								
Mollusca	Bivalvia	Sphaeriidae														2																
	Gastropoda	Hydrobiidae																							1					2		
		Gastr. Unid.																			1											
Annelida	Oligochaeta				23	9	12	21		1	11		8	14	8	26	49	47	26	43	4	6	10	15	4	3	2	12	3		21	7
Arachnida	Acarina										1											2		4	2	2	2		3	10		
Crustacea	Amphipoda	Paramelitidae													10	11	3	5			1	1			2		1	1				
		Neoniphargidae	1	34	1	4	1	1						1	1					1												
	Isopoda	Janiridae	41	43	10													1		1	8		1	3								
Insecta	Plecoptera	Eustheniidae	1		2	3	2		1		1				2	4			8	2	4	5	3	3	7	22	3	2	1	2	2	
		Austroperlidae		2					1																							
		Gripopterygidae	1		47	59	44	38	5	1	30		4	26	15	11	3	5	12	12	8	1	5	2	16	40	5	13	3	9	7	4
		Notonemouridae	1					1		3																						
	Ephemeroptera	Leptophlebiidae	25	37	4	2	12	12	7	23	19		5	15	16	19	15	33	31	19	49	39	43	51	45	19	83	36	37	46	57	72
		Baetidae													5			2	1	1	30	29	46	37	49	14	39	13	26	37	23	17
	Diptera	Chironomidae:Chironominae							1												1	1	1		1	1	1		1			
		Chironomidae:Orthocladiinae				2				1	1				1					1	3	1	3	2		3	2		9	1	1	
		Chironomidae:Podonominae	1	1									2							1	15	15	16	17	25	10	21	14	6	5	11	11
		Simuliidae	30	40	330	268	18	17	62	94	60		121	80	60	41	72	67	43	22	67	55	24	28	18	37	27	28	33	1	26	5
		Tipulidae			1		5	4					2		3	2			1	3	1	3		4			4	3	3	1		
		Athericidae																										1				
		Blephariceridae												2				1	2	2	2					1				1		
		Chaoboridae	1																													
		Empididae									2			1	2					1							1					
		Dip. Unid. Pup.																							1						1	
	Trichoptera	Calocidae														1								1			1				1	2
		Conoesucidae			1	3	1	2			1									1	1					3			6	7	1	11
		Glossosomatidae						5										2									1				3	13
		Hydrobiosidae	21	40	48	53	37	30	8	16	39		15	18	13	7	5	2	9	3	37	41	20	28	25	12	27	12	16	8	30	28
		Hydropsychidae									26		1	12	5	2			5	4			2			5	1	2	5	3		7
		Hydroptilidae																	1													
		Leptoceridae								1					3	2		1	1	3	9	18	5	11	21	9	4	2	5	6	3	11
		Philopotamidae																	1													
		Philorheithridae					1								3						4	3	4	8	2		3		2	7	2	3
		Trich. Unid. Pup.												1						1			3		1		1		9	4		1
	Coleoptera	ElmidaeA		1		1	1	2	1		2		5	5	11	3	1	2	1	2	37	32	23	18	14	18	13	20	58	26	20	
		ElmidaeL											2	2	4	2		1				4	11	7			5	1	6	4	1	
		ScirtidaeL	1				1	1		1					1			3			26	23	12	15	12	5	12	4	13	19	13	
		PsephenidaeL						2			1						1			1		2	3		1	2	3		1	2	2	2
		N Taxa	**12**	**9**	**10**	**11**	**13**	**14**	**8**	**9**	**13**	*****	**10**	**12**	**18**	**15**	**9**	**15**	**14**	**20**	**21**	**19**	**19**	**18**	**20**	**18**	**24**	**16**	**22**	**21**	**19**	**15**
		Total abundance	**145**	**223**	**467**	**406**	**136**	**137**	**86**	**141**	**194**	**0**	**165**	**177**	**163**	**134**	**152**	**176**	**142**	**124**	**309**	**281**	**235**	**254**	**248**	**206**	**262**	**164**	**247**	**201**	**225**	**194**

Table 7.7. O/E values derived from combined season 2004-05 RBA macroinvertebrate data for Gordon River and reference sites. O/EPa, O/Erk = derived using presence/absence and rand abundance data, respectively. Results shown for two replicate samples per site and their mean.

River	Site	Replicate	O/Epa	Band	O/Erk	Band
Gordon R	75	1	0.57	B	0.51	B
		2	0.64	B	0.58	B
		Mean	**0.61**	**B**	**0.54**	**B**
	74	1	0.71	B	0.47	B
		2	0.71	B	0.50	B
		Mean	**0.71**	**B**	**0.48**	**B**
	72	1	0.86	A	0.75	B
		2	0.86	A	0.75	B
		Mean	**0.86**	**A**	**0.75**	**B**
	69	1	0.50	B	0.35	C
		2	0.72	B	0.50	B
		Mean	**0.61**	**B**	**0.43**	**B**
	63	1	0.86	A	0.81	A
		2				
		Mean	**0.86**	**A**	**0.81**	**A**
	60	1	1.07	A	0.81	A
		2	0.93	A	0.90	A
		Mean	**1.00**	**A**	**0.86**	**A**
	57	1	1.03	A	1.05	A
		2	0.97	A	0.90	A
		Mean	**1.00**	**A**	**0.97**	**A**
	42	1				
		2	0.96	A	0.95	A
		Mean	**0.96**	**A**	**0.95**	**A**
	48	1	0.89	A	0.90	A
		2	0.96	A	0.97	A
		Mean	**0.92**	**A**	**0.94**	**A**
Franklin R	Fr11	1	1.15	X	1.07	A
		2	1.15	A	0.98	A
		Mean	**1.15**	**A**	**1.02**	**A**
	Fr21	1	1.23	X	1.16	X
		2	1.15	A	0.98	A
		Mean	**1.19**	**A**	**1.07**	**A**
Denison R	De7	1	1.15	A	1.07	A
		2	1.22	X	1.16	X
		Mean	**1.18**	**X**	**1.12**	**X**
	De35	1	1.15	A	0.96	A
		2	1.08	A	0.86	A
		Mean	**1.11**	**A**	**0.91**	**A**
Maxwell R	Ma7	1	1.22	X	1.12	X
		2	1.22	X	1.07	A
		Mean	**1.22**	**X**	**1.09**	**A**
Jane R	Ja7	1	1.15	A	0.98	A
		2	1.15	A	1.03	A
		Mean	**1.15**	**A**	**1.01**	**A**



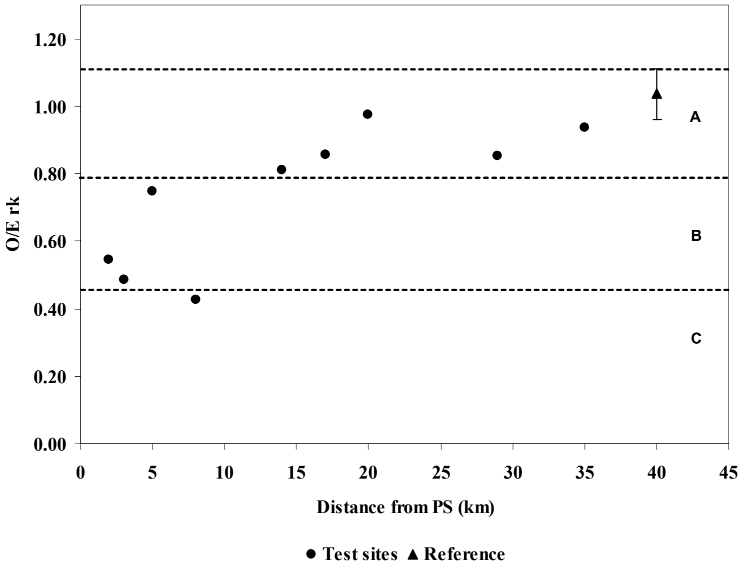


Figure 7.3. Trends in combined season O/Epa (top) and O/Erk (bottom) values for macroinvertebrates in the Gordon River with distance downstream of the Gordon Power Station in 2004-05. Mean values for reference sites sampled at the same time are also shown, with error bars (+/- 1 SD). Horizontal lines indicate bounds of impairment bands, A, B and C (see Davies & Cook 2001).

7.3.2.2 Single season O/E values

All RBA samples from years 1 to 4 (2001-02 to 2004-05) of pre-Basslink monitoring were analysed using the relevant autumn or spring models and O/Epa and O/Erk values were generated for each sampling occasion. Results for 2002-03, 2003-04 and 2004-05 were generated for each duplicate sample and the mean O/E values are reported in Table 7.8.

The trend in O/Epa and O/Erk was similar for all seasons, with lower values in the reaches immediately downstream of the power station but increasing with distance downstream. Reference sites values were higher.

There was little interannual variation in the trend, with some limited variation between seasons and years in actual O/E values for each site. Within the Gordon River, the autumn 2005 O/Erk data increased at some sites, was comparable to previous years while at some sites it decreased slightly compared to previous years (Table 7.8). Similarly, the reference site O/Erk values oscillated slightly compared to previous years. The overall level of variation between years was small.

Table 7.8. Single season O/E values for all sites monitored in the Gordon River and reference rivers from spring 2001 to autumn (April) 2005.

		Year :	**2001**		**2002**		**2002**		**2003**		**2003**		**2004**		**2004**		**2005**	
		Season :	**Spring**		**Autumn**		**Spring**		**Autumn**		**Spring**		**Autumn**		**Spring**		**Autumn**	
		OE output :	**OEpa**	**OErk**	**OEpa**	**OErk**	**OEpa**	**OErk**	**OEpa**	**OErk**	**OEpa**	**OErk**	**OEpa**	**OErk**	**OEpa**	**OErk**	**OEpa**	**OErk**
River		**Site**																
Gordon	G4	75	0.68	0.71	0.59	0.61	0.38	0.60	0.49	0.43	0.49	0.58	0.68	0.56	0.56	0.58	0.49	0.56
	G4a	74	0.66	0.64	0.88	0.66	0.81	0.61	1.03	0.83	0.63	0.73	0.88	0.73	0.74	0.88	0.78	0.50
	G5	72	0.87	0.97	0.88	0.71	0.69	0.77	0.88	0.73	0.80	0.92	1.03	0.73	0.87	0.83	1.08	0.86
	G6	69	0.91	1.12	0.98	0.73	0.68	0.61	0.78	0.74	0.87	0.81	0.83	0.68	0.64	0.76	0.64	0.47
	G7	63	1.04	1.16	1.27	1.11	1.08	1.06	1.17	0.95	0.82	0.94	1.17	1.03	0.74	0.68	0.98	0.81
	G9	60	0.90	1.12	1.37	1.11	0.90	1.14	1.17	0.83	1.05	1.02	1.27	0.91	1.01	0.96	0.88	0.58
	G10	57	0.97	1.06	1.08	0.86	1.05	1.12	1.27	1.08	0.86	0.85	1.42	1.03	1.09	1.06	1.37	0.96
	G11b	48	0.96	0.98	1.27	0.95	0.92	1.17	1.08	0.93	1.04	0.98	1.17	0.93	1.16	1.23	1.27	0.85
	G15	42	1.12	1.17	1.37	1.01	0.90	1.13	1.03	0.85	0.94	0.96	1.17	0.86	0.94	0.90	1.27	0.88
Reference																		
Franklin		Fr11	1.35	1.40	1.57	1.01	1.31	1.17	1.52	1.16	1.12	1.20	1.27	0.93	1.27	1.20	1.47	1.16
		Fr21	1.20	1.18	1.66	1.21	1.35	1.17	1.47	1.18	1.05	1.03	1.32	1.13	1.16	1.23	1.37	1.11
Denison		De7	0.91	1.00	1.66	1.36	1.18	1.14	1.42	1.13	1.37	1.23	1.52	1.19	1.40	1.29	1.32	1.16
		De35	1.11	1.03	1.66	1.21	1.11	1.01	1.32	1.14	0.91	1.04			0.91	0.83	1.56	1.19
Maxwell		Ma7	1.35	1.41	1.66	1.21	1.43	1.04	1.66	1.14	1.24	1.22	1.56	1.13	1.28	1.22	1.56	1.13
Jane		Ja7	1.34	1.15	1.47	1.06	1.26	1.07	1.47	1.19	1.11	1.16	1.52	1.24	1.22	1.16	1.42	0.96

7.3.3 Change between years

The overall pattern of total macroinvertebrate abundance, number of taxa, O/E values and the higher values for all these variables in reference river sites was consistent throughout the 4 years of monitoring (8 seasonal sampling trips). Annual variations were noted with regard to abundance and diversity at site 72 and occasional elevated abundance of filter-feeding groups (simuliids, hydropsychids) at sites in the vicinity of the Denison River junction. Both of these reflect the influence of the Albert and Denison Rivers on the reaches adjacent to their inflow.

Paired *t*-tests were conducted to initially assess between-year differences in total abundance, number of taxa, O/Epa and O/Erk. There were no significant differences between years for any of these parameters (all p >0.05). However, O/Epa and O/Erk were significantly different from each other, with O/Erk being smaller than O/Epa, in autumn 2002, 2003, 2004 and 2005 This is consistent with observations made by Davies *et al.* (1999) who described the impact of the Gordon River as being associated with both loss of taxa, resulting in reduced O/Epa values, and reductions in relative abundance of the remaining taxa, resulting in OErk being less than OEpa. There were no significant differences between O/Epa and O/Erk for the Gordon River sites in spring 2001, 2002, 2003 and 2004.

7.4 Conclusions

Overall patterns of diversity, community composition and abundance for 2001-02, 2002-03, 2003-04 and 2004-05 were similar to those observed previously in 1995-96 and 1998-99 as reported in Davies *et al.* (1999) and Davies & Cook (2001). This indicates there has been no substantial change since 1995-96. There is a degree of background variability in abundance, which this project was designed to observe and incorporate into the assessment of pre- vs post-Basslink changes.

O/E values for 2001-02, 2002-03, 2003-04 and 2004-05 followed the same trends as observed by Davies & Cook. (2001). Reference site values generally fell within the range previously established for the reference condition, as observed in previous years. Paired *t*-tests of O/Epa and O/Erk values for all sites did not suggest a significant change between this survey and those conducted in 1998-99, 2001-02, 2002-03, or 2003-04 (all with p >0.1). This indicates that no consistent or substantial change in O/E values had occurred across all sites between any of these dates.

8 Algae

8.1 Introduction

Benthic algae were surveyed in spring (October) 2004 and autumn (April 2005). Quantitative (quadrat-based) assessment of algal cover was conducted at nine monitoring sites in the Gordon River between the power station and the Franklin confluence.

8.2 Methods

8.2.1 Monitoring sites

The monitoring sites were the same as for the Basslink macroinvertebrate monitoring program conducted in the Gordon River (Figure 8.1).

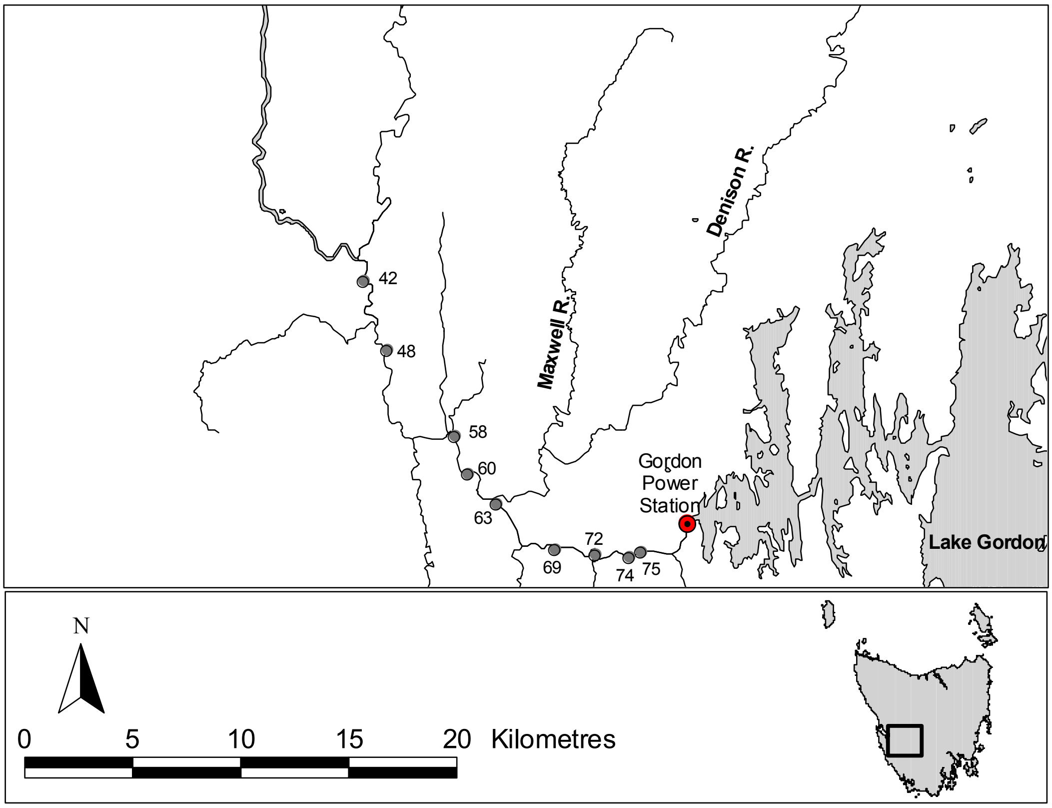


Figure 8.1. Map of the algal monitoring sites in the Gordon River.

Table 8.1. Sites sampled in October 2004 and April 2005 for benthic algae

River	Site name	Site code	Distance from power station (km)
Gordon	Gordon R d/s Albert Gorge (G4)	75	2
	Gordon R d/s Piguenit R (G4A)	74	3
	Gordon R in Albert Gorge (G5)	72	5
	Gordon R u/s Second Split (G6)	69	8
	Gordon R u/s Denison R (G7)	63	14
	Gordon R d/s Denison R (G9)	60	17
	Gordon R u/s Smith R (G10)	57	20
	Gordon R d/s Olga R (G11A)	48	29
	Gordon R @ Devil's Teapot (G15)	42	35

8.2.2 Benthic algal survey

All algal assessment was conducted by measuring percent area of cover at fixed distances along existing transects across the Gordon River, with one transect assessed at each site.

All algal monitoring in 2004-05 was conducted as follows:

- transects were re-established, perpendicular to the direction of river flow, by running a measuring tape across the river from the existing transect head-peg (which was designated as the zero distance offset) to a fixed peg on the opposite bank;
- algal density, as percent cover, was recorded using a 30 cm x 30 cm quadrat at 2.5 m intervals in three locations: 1 m upstream of the transect line; on the transect line; and 1 m downstream of the transect lines. Quadrat frames were fitted with a 100 cell wire grid to assist with areal cover estimates (as used for the first time in spring 2002); and
- within each quadrat, density was reported for four broad floristic groups: filamentous algae, characeous algae, moss and macrophytes.

Each transect was divided into broadly similar zones, characterised by consistency of benthic substrate composition. Zones were selected following visual inspection of the channel substrate, and defined in terms of their dominant substrate composition, e.g. cobble/gravel, sand/silt, sand/snags or bedrock.

Five scrapes of filamentous algae and moss were taken from the upper surface of boulders or cobbles in the centre of each zone at each site on all sampling occasions. The five scrapes were pooled, resulting in a single composite and representative sample of the dominant benthic species present within each zone. These samples were preserved in 10% formalin for later identification.

8.2.3 Analysis

Analysis for this report summarises plant cover scores. More detailed analyses are available within the Basslink Baseline Report. Mean plant cover was calculated for each transect for the channel bed. The channel bed was classified as either the section of channel between the toe of each bank (for those transects for which the entire channel could be surveyed) or between the toe of the bank and the furthest point of observation across the channel. The locations of the channel bed relative to the transect head peg are shown below in Table 8.2.

Table 8.2. Extent of channel bed for which mean cover was calculated.

Site	Channel bed (offset from peg, m)
75	5 - 60
74	7.5 - 60
72	5 - 92.5
69	10 - 75
63	7.5 - 70
60	9 - 87.5
57	7.5 - 55
48	7.5 - 72.5
42	7.5 - 47.5

8.3 Results

8.3.1 2004-05

Surveys were successfully completed across the entire river channel for sites 75, 74, 72, 69, 63 and 60. The presence of deep, fast flowing water in both October 2004 and April 2005 again prevented a survey across the entire channel for sites 57, 48 and 42. In October, an average of 64 m of river bed was surveyed across all sites, ranging from 42.5 to 90 m, while in April an average of 71 m was surveyed ranging from 47.5 to 100 m (Table 8.3). Both monitoring trips revealed that aquatic flora had a consistently low to moderate cover across all sites. Moss and filamentous algae were the dominant forms with low mean percent cover across all sites of 2.8 and 4.4%, respectively in April 2005. Greatest cover of both forms was found at sites 74 and 75. Characeous algae, comprising *Chara* and *Nitella* species, were observed in April 2005 at sites 74 (2.64%), 72 (0.25%) and 63 (0.03%), whereas in October 2004 they were found only at site 57 (0.02% cover). Macrophytes with *Callitriche* species (starworts) and *Isolepis fluitans* were recorded in October 2004 at site 72 (0.01%), but not in April 2005.

The change in moss and filamentous algae cover with distance from the Gordon Power Station for the autumn sampling period is shown in Table 8.3. A trend of decreasing cover was again evident with distance from the station in the autumn 2005 data.

Table 8.3. Mean percent cover for moss, filamentous algae, Chara and macrophytes surveyed in the Gordon River during a) spring (October) 2004 and b) autumn (April) 2005.

a) - spring 2004

Site	Mean cover (%) Moss	Filamentous algae	Nitella/Chara	Macrophytes	Width surveyed (m)
Gordon					
75	1.69	13.81	0	0	67.5
74	13.79	19.68	0	0	62
72	1.01	4.70	0	0.01	78
69	0.42	9.60	0	0	40
63	2.63	2.79	0	0	77.5
60	2.27	0	0	0	90
57*	0.23	0.99	0.02	0	52.5
48*	2.72	2.28	0	0	65
42*	0.34	3.33	0	0	42.5
Reference					
Fr11	0.00	1.43	0	0	
Ja7	0.10	2.10	0.03	0	
De35	0.00	0.50	0	0	

b) - autumn 2005

Site	Mean % cover Moss%	Filamentous algae %	Nitella/Chara %	Macrophytes %	Width surveyed (m)
Gordon					
75	8.13	14.16	0	0	67.5
74	11.45	15.19	2.64	0	70
72	0.07	5.04	0.25	0	80
69	1.09	0.29	0	0	82.5
63	1.66	0.31	0.03	0	75
60	1.69	0	0	0	87.5
57*	0.27	1.40	0	0	52.5
48*	0.46	1.39	0	0	77.5
42*	0.47	1.67	0	0	47.5
Reference					
Fr11	0	2.73	0	0	
Fr21	0	3.13	0	0	
De7	0	0.03	0	0	

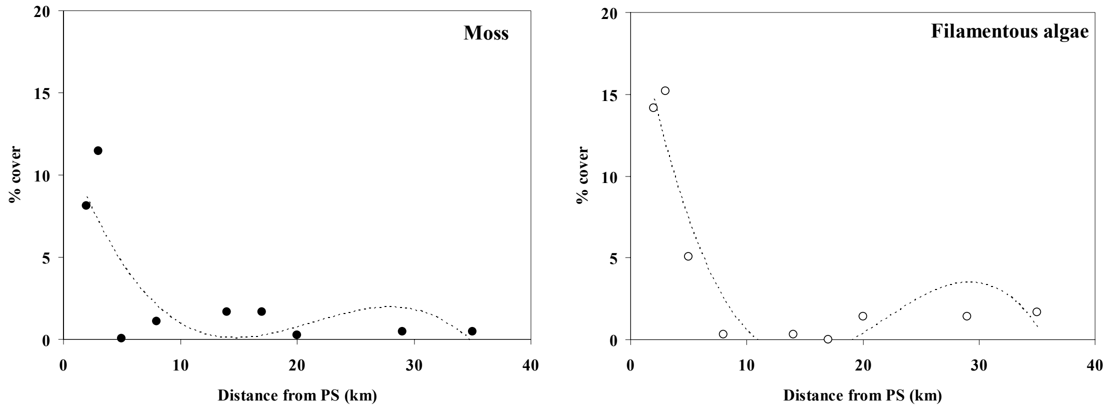


Figure 8.2. Mean annual cross-channel cover of moss (top panel) and filamentous algae (bottom panel) at each of the sampling sites within the Gordon River plotted as distance from the power station (PS) for Autumn 2005.

8.3.2 Between-year comparisons

Overall mean percent cover for moss and filamentous algae are shown for all sites for each year as means across each transect over the two sampling occasions (Table 8.4). Pairwise *t*-tests were conducted to assess changes in the mean annual cover in the Gordon River below the power station between the 2002-03, 2003-04 and 2004-05 years. There was no significant difference in percent cover of either moss or filamentous algae between 2003-04 and 2004-05. The annual mean moss and filamentous algal cover for all four years of 2001-02, 2002-03, 2003-04 and 2004-05 are shown in Figure 8.3.

Table 8.4. Annual mean percent cover for moss and filamentous algae at all transects in the Gordon River for the pre-Basslink monitoring program of 2001-02 to 2004-05.

	01/02 mean		02/03 mean		03/04 mean		04/05 mean	
Site	**Moss**	**Filamentous**	**Moss**	**Filamentous**	**Moss**	**Filamentous**	**Moss**	**Filamentous**
75	6.09	7.79	2.07	9.88	2.09	10.10	4.91	13.99
74	10.63	17.00	8.16	20.73	6.18	9.08	12.62	17.43
72	0.14	1.86	1.06	2.18	0.07	1.18	0.54	4.87
69	8.50	3.35	3.42	5.28	1.64	1.56	0.76	4.95
63	1.05	2.19	2.46	6.59	2.15	6.31	2.14	1.55
60	0.33	1.51	0.13	0.03	0.98	0.18	1.98	0.00
57	0.80	0.01	0.25	0.09	0.75	0.00	0.25	1.20
48	2.84	1.72	0.54	0.26	0.87	0.32	1.59	1.84
42	3.10	3.72	0.06	0.44	0.62	0.67	0.41	2.50
Grand mean	**3.72**	**4.35**	**2.01**	**5.05**	**1.71**	**3.27**	**2.80**	**5.37**
Mean upstream Denison	**5.28**	**6.44**	**3.43**	**8.93**	**2.43**	**5.65**	**4.19**	**8.56**
Mean downstream Denison	**1.77**	**1.74**	**0.24**	**0.21**	**0.81**	**0.29**	**1.06**	**1.38**

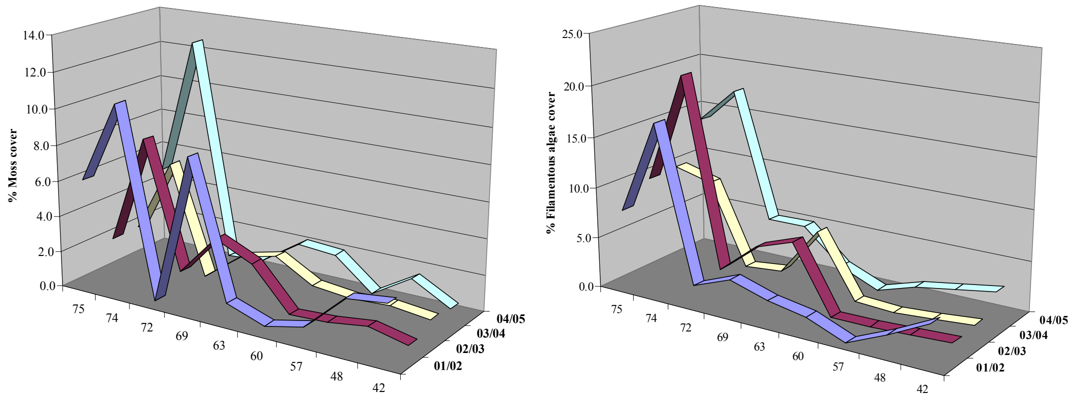


Figure 8.3. Downstream trend in mean moss (left) and filamentous algae (right) percent cover in the Gordon River between 2001-02 to 2004-05.

8.4 Conclusions

As in 2001-02, 2002-03, 2003-04 and spring 2004, moss and filamentous algal cover remained low (at less than 9% with an overall mean of 2-4% cover across all transects) and tended to decrease from the Gordon Power Station to the Franklin junction.

9 Fish

9.1 Introduction

The specific aims of the Gordon River fish monitoring are to:

- quantify pre- and post-Basslink variability in the relative abundance of fish populations to allow statistical comparison between these times and appropriate reference sites;
- assess potential changes in the longitudinal fish community structure of the Gordon River with the aim of identifying any changes in the zone of influence;
- detect and assess potential changes in catch per unit effort which may result from Basslink operations;
- determine the incidence of fish stranding; and
- determine any changes to the fish populations of affected tributaries, in particular, if recruitment success for juvenile galaxiids is changed under Basslink.

This section summarises the results of the fourth year of the pre-Basslink fish monitoring surveys. A comprehensive analysis of the four year pre-Basslink dataset is contained in the Basslink Baseline Report.

9.2 Methods

The 2004-05 monitoring was conducted in December 2004 and April 2005. Six previous monitoring surveys have been completed, and these were conducted in December 2001, April and December 2002, March and November 2003, and April 2004.

Figure 9.1 shows the location the Gordon catchment monitoring zones. Thirty-one Gordon catchment 'test' sites, located in zones 1 to 5, were scheduled for sampling on each occasion (Table 9.1). The rationale behind the zone allocations is discussed in Howland *et al.* (2001). Seven river and four tributary reference sites were scheduled for sampling in conjunction with the test sites, and these are listed in Table 9.2. These tables give the general locations of the sample sites.

'Optional' sites, listed in Table 9.3, were included in the monitoring regime and consisted of 11 test and 3 reference sites that were located in both tributaries and rivers. These sites were included to provide additional data for the monitoring program in the event of failure to sample some of the core sites due to poor weather or logistical reasons. 'Optional' sites were sampled if time and logistics permitted it, however core sites took priority in the sampling regime. The Orange River test site (formerly classified as optional) has been reclassified as core following ongoing access problems with the Denison upstream Maxwell site.

Figure 9.1. Fish monitoring zones in the Gordon R. (1-5); Franklin R. (7-8); Birches Inlet (9); and Henty River (13-14).

Table 9.1. Gordon catchment (test) monitoring sites. Alternative site names are shown in parenthesis.

Zone	River Sites	Tributary Sites
1	75 (G4), 74 (G4a), 73 (G3) u/s and d/s	Serpentine River, Indigo Creek, Piguenit Rivulet
2	72 (G5) upper and lower, 71 (G5a pipe and water meter) and 69 (G6)	Albert River, Splits Creek and Mudback Creek
3	68 (G6a), 63 (G7) and 57 (G16)	Smith River and Harrison Creek, Denison River u/s Gorge, Denison River @ Maxwell, Orange River
4	54 (Howards Creek), 51 (Platypus Creek), 46 (Gordon u/s Sprent)	Howards Creek, Olga River, Platypus Creek and Sprent River
5	45 (Gordon d/s Sprent), 44 (G14), 42 (G15)	Franklin @ Pyramid Island

Table 9.2. Reference monitoring sites.

Zone (catchment)	River sites	Tributary sites
7 (Franklin)	Franklin d/s Big Fall	none
8 (Franklin)	Franklin u/s Big Fall Franklin @ Canoe Bar	Forester Creek, Ari Creek, Wattle Camp Creek
9 (Birches Inlet)	Sorell River	Pocacker River
13 (Henty)	Henty u/s Bottle Creek Henty @ Yolande River	None
14 (Henty)	Henty @ Sisters	None

Table 9.3. Optional sites surveyed during the monitoring program. Alternative site names are shown in parenthesis.

Zone	River Sites	Tributary Sites
1	76 (G2)	Left bank Creek @ site 75
2	Gordon @ Grotto Creek	Grotto Creek
3	Site 60 (G9), Gordon @ G8, Gordon @ Fluffies	Denison @ Denison Camp
4	none	Howards Creek inundation, Olga @ riffles
5	Gordon @ Angel Cliffs	none
8 (Franklin)	Franklin @ Forester Creek, Franklin @ Wattle Camp Creek	none
14 (Henty)	Henty @ West Sister	none

All essential sites and nine optional sites were sampled in December 2004. One reference site, Franklin downstream of Big Fall, could not be sampled in April 2005 due to high flows, but seven optional sites were sampled.

Table 9.4 summarises the sites sampled during each of the 8 fishing surveys carried out between December 2001 and April 2005 inclusive, and lists classification information, zone allocation and sampling priority of each site.

Fish surveys were undertaken by backpack electrofishing, following the methods detailed in Howland *et al.* (2001). Surveys of the Gordon test sites were conducted by three, two-person teams, with a target electrofishing effort of 1200 seconds shocking time for each site. Gordon catchment tributary sites situated outside the power station zone of influence were sampled by two teams, and a single team sampled the out of catchment reference sites.

Fish teams sample a range of representative habitats at each site. Fish are identified, counted and fork lengths are recorded to the nearest millimetre. Qualitative assessments of general aquatic habitat descriptors are recorded for each site.

Table 9.4. Fish monitoring sites sampled between December 2001 and April 2005, including site classification information. ! represents essential sites that could not be sampled.

Zone	Type	class	priority	Site name	site no	Dec 2001	Apr 2002	Dec 2002	Mar 2003	Nov 2003	Apr 2004	Dec 2005	Apr 2005
1	River	test	essential	Gordon @ G3 (d/s)	73	■	■	■	■	■	■	■	■
1	River	test	essential	Gordon @ G3 (u/s)	73	■	■	■	■	■	■	■	■
1	River	test	essential	Gordon @ G4	75	■	■	■	■	■	■	■	■
1	River	test	essential	Gordon @ G4a	74	■	■	■	■	■	■	■	■
1	River	test	optional	Gordon @ G2	76		■		■	■		■	
1	Tributary	test	essential	Indigo Creek		■	■	■	■	■	■	■	■
1	Tributary	test	essential	Piguenit Rivulet		■	■	■	■	■	■	■	■
1	Tributary	test	essential	Serpentine River		■	■	■	■	■	■	■	■
1	Tributary	test	optional	Left bank creek at G4		■							
2	River	test	essential	Gordon @ G5 (lower)	72	■	■	■	■	■	■	■	■
2	River	test	essential	Gordon @ G5 (upper)	72	■	■	■	■	■	■	■	■
2	River	test	essential	Gordon @ G5a (pipe)	71	■	■	■	■	■	■	■	■
2	River	test	essential	Gordon @ G5a (water)	71	■	■	■	■	■	■	■	■
2	River	test	essential	Gordon @ G6	69	■	!	■	■	■	■	■	■
2	River	test	optional	Gordon @ Grotto Creek	64		■		■			■	■
2	Tributary	test	essential	Albert River		■	■	■	■	■	■	■	■
2	Tributary	test	essential	Mudback Creek		■	!	■	■	■	■	■	■
2	Tributary	test	essential	Splits Creek		■	■	■	■	■	■	■	■
2	Tributary	test	optional	Grotto Creek					■	■		■	■
3	River	test	essential	Gordon @ G7	63	■	■	■	■	■	■	■	■
3	River	test	essential	Gordon @ Harrison Creek (G16)	57	■	■	■	■	■	■	■	■
3	River	test	essential	Gordon @ Orange River (G6a)	68	■	■	■	■	■	■	■	■
3	River	test	optional	Gordon @ G9	60	■			■				■
3	River	test	optional	Gordon @ G8		■				■	■	■	
3	River	test	optional	Gordon @ Fluffies					■	■		■	■
3	Tributary	test	essential	Denison u/s Gorge		■	■	■	■	■	■	■	■
3	Tributary	test	removed	Denison u/s Maxwell		!	!	removed	removed	removed	removed	removed	removed
3	Tributary	test	essential	Denison @ Maxwell River		!	■	■	■	■	■	■	■
3	Tributary	test	essential	Harrison Creek		■	■	■	■	■	■	■	■
3	Tributary	test	essential	Smith River		■	■	■	■	■	■	■	■
3	Tributary	test	opt/essent	Orange River		optional	optional	essential	essential	essential	essential	essential	essential
3	Tributary	test	optional	Denison @ Denison Camp			■						
4	River	test	essential	Gordon @ Howards Creek	54	■	■	■	■	■	■	■	■
4	River	test	essential	Gordon @ Platypus Creek	51	■	■	■	■	■	■	■	■
4	River	test	essential	Gordon u/s Sprent River	46	■	■	■	■	■	■	■	■
4	Tributary	test	essential	Howards Creek		■	■	■	■	■	■	■	■
4	Tributary	test	essential	Olga @ Gordon		■	■	■	■	■	■	■	■
4	Tributary	test	essential	Platypus Creek		■	■	■	■	■	■	■	■
4	Tributary	test	essential	Sprent River		■	■	■	■	■	■	■	■
4	Tributary	test	optional	Howards Creek inundation		■							
4	Tributary	test	optional	Olga @ Riffles			■	■	■	■	■	■	■
5	River	test	essential	Gordon @ G14	44	■	■	■	■	■	■	■	■
5	River	test	essential	Gordon @ G15	42	■	■	■	■	■	■	■	■
5	River	test	essential	Gordon d/s Sprent River	45	■	■	■	■	■	■	■	■
5	River	test	optional	Gordon @ Angel Cliffs	45a	■	■	■	■	■	■	■	■
5	River	test	essential	Franklin @ Pyramid Island		■	■	■	■	■	■	■	■
7	River	reference	essential	Franklin d/s Big Fall		■	■	■	■	■	■	■	high flows
8	River	reference	essential	Franklin @ Canoe Bar		■	■	■	■	■	■	■	■
8	River	reference	essential	Franklin u/s Big Fall		■	■	■	■	■	■	■	■
8	River	reference	optional	Franklin @ Forester Creek		■	■	■	■		■	■	
8	River	reference	optional	Franklin @ Wattle Camp Creek		■	■	■	■	■	■	■	■
8	Tributary	reference	essential	Ari Creek		■	■	■	■	■	■	■	■
8	Tributary	reference	essential	Forester Creek		■	■	■	■	■	■	■	■
8	Tributary	reference	essential	Wattle Camp Creek		■	■	high flows	■	■	■	■	■
9	River	reference	essential	Sorell River		■	■	■	■	■	■	■	■
9	Tributary	reference	essential	Pocacker River		!	■	■	■	■	■	■	■
13	River	reference	essential	Henty @ Yolande		■	■	■	■	■	■	■	■
13	River	reference	essential	Henty u/s Bottle Creek		■	■	■	■	■	■	■	■
14	River	reference	essential	Henty @ Sisters		■	■	■	■	■	■	■	■
14	River	reference	optional	Henty @ West Sister		■							

The Fish monitoring zones are shown in Figure 9.1 and defined a follows:

Zone 1: Gordon River and tributaries from Gordon Power Station tailrace downstream to, and inclusive of, Abel Gorge

Zone 2: Gordon River and tributaries from Albert River downstream to the First Split

Zone 3: Gordon River and tributaries from the Orange River downstream to Sunshine Falls

Zone 4: Gordon River and tributaries from Sunshine Falls to the Sprent River

Zone 5: Gordon River from Angel Cliffs downstream to Big Eddy

Zone 7: Franklin River between Pyramid Island and Big Fall

Zone 8: Franklin River and tributaries upstream of Big Fall

Zone 9: Birches Inlet catchment

Zone 13 Henty River at or downstream of the Yolande River

Zone 14: Henty River upstream of the Yolande River

9.3 Hydrological conditions

Figure 9.2 and Figure 9.3 show discharge from the Gordon Power Station, and at the Gordon River above Franklin site, the Franklin River at Mount Fincham site and the Collingwood River below Alma River site prior to, and during, the summer and autumn surveys, respectively.

Gordon Power Station was not generating during mid November 2003, and a natural flow event is clearly evident in the Franklin, Gordon and Collingwood Rivers between 14-16 November 2004. The power station recommenced generating in late November, with discharge to the river gradually increasing to approximately 200 $m^3 s^{-1}$ prior to the sampling shut down.

Power station discharge generally ranged between 130 - 220 $m^3 s^{-1}$ in the month prior to the autumn shut down. A moderate increase in flows occurred in the tributary sites during the week prior to the monitoring trip. Flows had subsided so that most tributary sites could be sampled, although the Franklin below Big Fall site could not be accessed due to high flows.

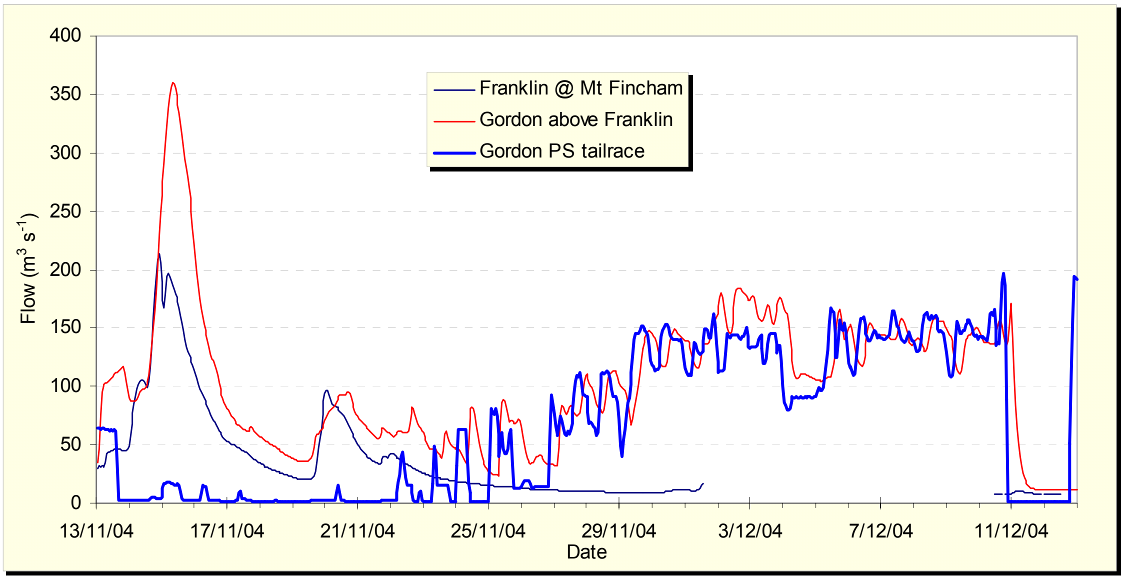


Figure 9.2. Discharge (m^3 s^{-1}) from the Gordon Power Station, Gordon River above Franklin, and Franklin at Mt Fincham sites between November and December 2004.

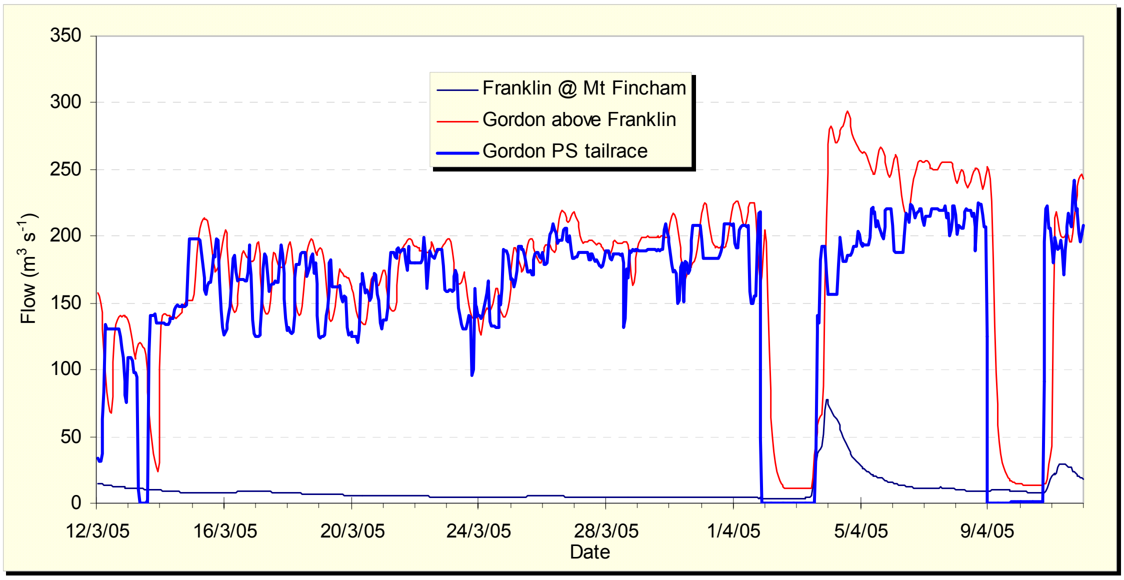


Figure 9.3. Discharge (m^3 s^{-1}) from the Gordon Power Station, Gordon River above Franklin, and Franklin at Mt Fincham sites between March and April 2005.

9.4 Results and discussion

Catch summaries for zones and catch per unit effort statistics (fish per 1200 seconds) for each zone are presented in Table 9.5 and Table 9.6, respectively. A total of 743 fish from 10 species were captured during the December 2004 survey. Two exotic species (*Salmo trutta* and *Perca fluviatilis*), one eel species (*Anguilla australis*), 2 species of lamprey (*Mordacia mordax* and *Geotria australis*) and four galaxiids (*Galaxias brevipinnis, G. maculatus, G. truttaceus, and Neochanna cleaveri*), the Sandy (*Pseudaphritis urvillii*) and a single Australian grayling (*Prototroctes maraena*) were collected during the survey. Catches in April 2005 were lower in numbers and diversity, with a total of 469 fish captured from 8 species. Tasmanian mudfish (*N. cleaveri*) and Australian grayling (*P. maraena*) were absent from the autumn catches.

A general summary of the 2004-05 (summer and autumn) data is provided in this report, with a particular focus on the Gordon and Franklin catchment sites. The complete 2001-05 data set will be analysed in the fish monitoring chapter of the Basslink Baseline Report.

Table 9.5. Numbers of each fish species caught in December 2004 and April 2005, summarised by site type and zone.

December 2004

Zone	Type	Shocker Effort (s)	*A. australis*	*G. australis*	*G. brevipinnis*	*N. cleaveri*	*G. maculatus*	*G. truttaceus*	*P. fluviatilis*	*P. maraena*	*P. urvillii*	*S. trutta*
1	River (Gord.)	6170	0	0	0	0	0	0	0	0	0	1
2	River (Gord.)	7586	0	0	0	0	0	0	8	0	0	13
3	River (Gord.)	6212	11	4	0	0	0	0	0	0	1	19
4	River (Gord.)	3345	13	0	3	0	2	12	0	0	1	12
5	River (Gord.)	6486	19	4	65	0	55	94	0	0	24	9
7	River (Frank.)	1291	3	0	13	0	0	6	0	0	3	0
8	River (Frank.)	5166	14	1	10	0	1	6	0	0	1	5
1	Tributary (Gord.)	3661	0	0	12	0	0	0	0	0	0	1
2	Tributary (Gord.)	4781	0	0	0	0	0	0	0	0	0	15
3	Tributary (Gord.)	6461	7	0	0	0	0	0	0	0	1	35
4	Tributary (Gord.)	6593	3	3	0	0	0	8	0	0	0	33
8	Tributary (Frank)	3787	1	0	3	0	0	8	0	0	0	11
9	River (Birches)	3298	24	0	0	0	3	12	0	0	21	0
13	River (Henty)	2909	1	10	15	5	3	60	0	1	0	1
14	River (Henty)	1403	3	0	0	0	0	1	0	0	2	7

April 2005

Zone	Type	Shocker Effort (s)	*A. australis*	*G. australis*	*G. brevipinnis*	*G. truttaceus*	*M. mordax*	*P. fluviatilis*	*P. urvillii*	*S. trutta*
1	River (Gord.)	4984	1	0	0	0	0	3	0	1
2	River (Gord.)	7170	0	6	0	0	0	3	0	8
3	River (Gord.)	6288	8	11	1	0	0	0	0	11
4	River (Gord.)	3699	6	7	0	24	0	0	2	0
5	River (Gord.)	6187	15	10	26	32	0	0	3	2
8	River (Frank.)	5174	2	3	0	1	0	0	0	6
1	Tributary (Gord.)	3701	0	0	0	0	0	0	0	0
2	Tributary (Gord.)	4838	0	1	0	0	0	0	0	23
3	Tributary (Gord.)	6159	5	0	0	0	0	0	0	80
4	Tributary (Gord.)	6122	3	2	0	12	1	0	1	29
8	Tributary (Frank)	3693	0	0	1	13	0	0	0	7
9	River (Birches)	2517	1	1	0	2	0	0	14	0
13	River (Henty)	2524	0	2	0	44	0	0	13	4
14	River (Henty)	1285	0	5	0	1	0	0	0	12

Table 9.6. Catch per unit effort for each fish species caught in December 2004 and April 2005, summarised by site type and zone.

December 2004

Zone	Type	Shocker Effort (s)	*A. australis*	*G. australis*	*G. brevipinnis*	*N. cleaveri*	*G. maculatus*	*G. truttaceus*	*P. fluviatilis*	*P. maraena*	*P. urvillii*	*S. trutta*
1	River (Gord.)	6170	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
2	River (Gord.)	7586	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.00	0.00	2.06
3	River (Gord.)	6212	2.12	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.19	3.67
4	River (Gord.)	3345	4.66	0.00	1.08	0.00	0.72	4.30	0.00	0.00	0.36	4.30
5	River (Gord.)	6486	3.52	0.74	12.03	0.00	10.18	17.39	0.00	0.00	4.44	1.67
7	River (Frank.)	1291	2.79	0.00	12.08	0.00	0.00	5.58	0.00	0.00	2.79	0.00
8	River (Frank.)	5166	3.25	0.23	2.32	0.00	0.23	1.39	0.00	0.00	0.23	1.16
1	Tributary (Gord.)	3661	0.00	0.00	3.93	0.00	0.00	0.00	0.00	0.00	0.00	0.33
2	Tributary (Gord.)	4781	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.76
3	Tributary (Gord.)	6461	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	6.50
4	Tributary (Gord.)	6593	0.55	0.55	0.00	0.00	0.00	1.46	0.00	0.00	0.00	6.01
8	Tributary (Frank)	3787	0.32	0.00	0.95	0.00	0.00	2.53	0.00	0.00	0.00	3.49
9	River (Birches)	3298	8.73	0.00	0.00	0.00	1.09	4.37	0.00	0.00	7.64	0.00
13	River (Henty)	2909	0.41	4.13	6.19	2.06	1.24	24.75	0.00	0.41	0.00	0.41
14	River (Henty)	1403	2.57	0.00	0.00	0.00	0.00	0.86	0.00	0.00	1.71	5.99

April 2005

Zone	Type	Shocker Effort (s)	*A. australis*	*G. australis*	*G. brevipinnis*	*G. truttaceus*	*M. mordax*	*P. fluviatilis*	*P. urvillii*	*S. trutta*
1	River (Gord.)	4984	0.24	0.00	0.00	0.00	0.00	0.72	0.00	0.24
2	River (Gord.)	7170	0.00	1.00	0.00	0.00	0.00	0.50	0.00	1.34
3	River (Gord.)	6288	1.53	2.10	0.19	0.00	0.00	0.00	0.00	2.10
4	River (Gord.)	3699	1.95	2.27	0.00	7.79	0.00	0.00	0.65	0.00
5	River (Gord.)	6187	2.91	1.94	5.04	6.21	0.00	0.00	0.58	0.39
8	River (Frank.)	5174	0.46	0.70	0.00	0.23	0.00	0.00	0.00	1.39
1	Tributary (Gord.)	3701	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Tributary (Gord.)	4838	0.00	0.25	0.00	0.00	0.00	0.00	0.00	5.70
3	Tributary (Gord.)	6159	0.97	0.00	0.00	0.00	0.00	0.00	0.00	15.59
4	Tributary (Gord.)	6122	0.59	0.39	0.00	2.35	0.20	0.00	0.20	5.68
8	Tributary (Frank)	3693	0.00	0.00	0.32	4.22	0.00	0.00	0.00	2.27
9	River (Birches)	2517	0.48	0.48	0.00	0.95	0.00	0.00	6.67	0.00
13	River (Henty)	2524	0.00	0.95	0.00	20.92	0.00	0.00	6.18	1.90
14	River (Henty)	1285	0.00	4.67	0.00	0.93	0.00	0.00	0.00	11.21

9.4.1 Exotic species

9.4.1.1 Brown trout

Brown trout catches were similar between the summer and autumn surveys. A total of 162 brown trout were captured in December 2004 and 183 in April 2005. To date, brown trout have dominated the total mean CPUE for each baseline survey.

Table 9.5 shows catch rates of all species for both the December 2004 and April 2005 surveys. During the December 2004 sample, brown trout catch rates were the highest of all species in zones 1-3 (for river sites), zones 2-8 (for tributary sites), and in the upper Henty River (zone 14). A similar trend was evident in April 2005, however redfin perch recorded the highest catch rate in zone 1 river sites, and spotted galaxias recorded the highest catch rate of all species in zone 8 tributaries.

Table 9.7 shows brown trout catch rates recorded over the duration of the monitoring period. Catches were similar to past levels in most instances for the Gordon river zones, and were in the higher range for the middle Gordon tributary site zones. Trout were not collected from the Birches Inlet rivers (zone 9) during either survey, which is consistent with the pattern of very low and infrequent catches collected in previous surveys.

Table 9.7. Catch Per Unit Effort (fish per 1200 seconds) for *S. trutta* in all riversites of all zones between December 2001 and April 2005.

Zone	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05
1	0.74	0.20	0.25	0.20	0.56	0.24	0.19	0.24
2	5.34	2.11	2.58	3.48	1.70	2.17	2.06	1.34
3	7.50	1.62	1.59	3.47	13.45	2.30	3.67	2.10
4	3.24	2.26	0.77	2.62	3.12	2.18	4.30	0
5	2.08	0.94	1.81	0.95	1.48	0.90	1.67	0.39
7	1.91	2.51	0	0	4.96	0	0	na
8	6.12	8.05	3.73	5.46	6.43	3.60	1.16	1.39
9	0	0	0	0.45	0	0.45	0	0
13-14	11.26	4.36	1.99	5.67	1.67	4.71	2.23	5.04

Table 9.8. Catch Per Unit Effort (fish per 1200 seconds) for *S. trutta* in all tributary sites of all zones between December 2001 and April 2005.

Zone	Dec-01	Apr-02	Dec 02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05
1	1.29	3.15	1.30	0.97	0.94	1.05	0.33	0
2	3.77	2.15	3.87	3.17	4.85	2.34	3.76	5.70
3	8.98	10.58	5.22	14.44	13.82	8.21	6.50	15.59
4	7.93	5.30	3.20	8.47	1.74	8.02	6.01	5.68
5	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-
8	5.62	5.43	2.38	2.42	2.89	5.35	3.49	2.27
9	-	-	-	-	-	-	-	-
13-14	-	-	-	-	-	-	-	-

9.4.1.2 Redfin perch

Table 9.9 shows the location and number of redfin perch captured in the Gordon River between December 2001 and April 2005, and Table 9.10 lists the catch rate in zones 1 and zone 2. Catches of redfin were relatively low during both summer and autumn surveys. Eight redfin were captured in December 2004, all of which were collected from zone 2 river sites. Six redfin were captured in April 2005, with catches split evenly between zones 1 and 2. To date, redfin have not been captured from the tributaries, and the range of this species does not appear to have increased since their discovery in December 2001. In fact, the pooled zone 1-2 catch rates are the lowest recorded since the species was reported from the middle Gordon River in December 2001. Redfin did, however, recorded the highest species catch rate for zone 1 during the autumn survey.

Relative abundance data from previous surveys indicated that redfin may have been exhibiting a seasonal change in abundance between zones 1 and 2, with catches higher in zone 1 during summer and autumn catches higher in zone 2. There are insufficient data to statistically test this hypothesis, and the data from December 2004 and April 2005 have not continued this possible trend.

Table 9.9. Capture locations and numbers caught for redfin perch (*Perca fluviatilis*) between December 2001 and April 2005. (*stranded on river bank, N/S represents site not sampled).

Site	Dec-01	Apr-02	Dec 02	March-03	Nov-03	Apr-04	Dec-04	Apr-05
Zone 1								
Gordon @ Serpentine	*2	N/S	N/S	N/S	N/S	N/S	N/S	N/S
Site 76 (Gordon @ G2)	N/S	0	N/S	0	0	N/S	0	N/S
Site 75 (Gordon @ G4)	0	0	3	0	11	0	0	0
Site 74 (Gordon @ G4a)	0	0	2	0	1	0	0	0
Site 73 (Gordon @ G3, d/s)	0	2	0	3	1	1	0	0
Site 73 Gordon @ G3, u/s)	0	0	0	0	0	0	0	3
Zone 2								
Site 72 (Gordon @ G5, lower)	0	2	0	3	0	5	2	1
Site 72 (Gordon @ G5, upper)	0	7	2	13	0	1	3	0
Site 71 (Gordon @ G5a, pipe)	0	0	0	0	0	1	0	0
Site 71(Gordon @ G5a, water)	0	2	0	2	0	1	3	2
Site 69 (Gordon @ G6)	1	N/S	0	0	0	0	0	0
Site 64 (Gordon @ Grotto Creek)	N/S	0	N/S	0	0	N/S	0	0
TOTALS	3	13	7	21	13	9	8	6

Table 9.10. Redfin perch CPUE in the Gordon River zones between December 2001 and April 2005. CPUE statistics were calculated on fish captured by electrofishing, and *excludes stranded or hand collected fish.

Zone	Dec-01	Apr-02	Dec 02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05
1	0*	0.40	1.23	0.61	2.42	0.24	0	0.72
2	0.25	2.11	0.32	1.55*	0.00	1.58	1.27	0.50
1 & 2 pooled	0.11	1.27	0.68	1.18	1.22	0.98	0.70	0.59

9.4.2 Eels and lampreys

9.4.2.1 Short headed lampreys

Mordacia mordax were absent from all sites during the December 2004 survey, and only a single ammocoete was collected from Howards Creek (tributary, zone 4) in April 2005.

9.4.2.2 Pouched lampreys

As per previous surveys, pouched lampreys were more numerous and showed a wider distribution in comparison to *Mordacia mordax*. Catches were highest in autumn survey, with a total of 48 fish returning a total "across zone" CPUE of 0.90, Catches were predominantly ammocoetes, which were collected from most zones. Summer catches rates were lower, returning a total "across zone" CPUE of 0.38.

Table 7 shows CPUE's for *G. australis* between December 2001 and April 2005 in the Gordon, Franklin and Henty river zones. The December 2004 and April 2005 catches rates were within the mid range of historical data in for most zones, but were the highest on record for zone 2 in the autumn survey.

Table 9.11. CPUE (standardised to fish per 1200 seconds) for *G. australis* in all river zones between December 2001 and April 2005.

Zone	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05
Zone 1 river sites	0	0	0	0	0	0	0	0
Zone 2 river sites	0	0	0	0.13	0	0	0	1
Zone 3 river sites	0	4.55	0.64	5.12	1.75	0	0.77	2.10
Zone 4 river sites	0	1.29	0	2.94	4.52	0	0	2.27
Zone 5 river sites	1.66	2.11	0.23	2.46	0	0.54	0.74	1.94
Zone 7 river sites	0	2.74	0	1.90	0	0	0	-
Zone 8 river sites	0	0	0	2.57	1.69	1.20	0.23	0.7
Zone 9 sites	0	1.25	0	4.50	1.31	0	0	0.48
Zone 13-14 sites	0	1.03	1.14	6.86	5.84	0.29	2.78	2.21

9.4.2.3 Short-finned eels

Catch rates for short-finned eels (*Anguilla australis*) are shown in Table 9.12. Catches were greater in the summer sample, which recorded a total "across zone" CPUE of 1.72 in comparison to the autumn CPUE of 0.76. Summer eel catches in zones 4, 8 and 9 were the highest of all species. Eels were caught in all test zones downstream of zone 2, and from all reference zones during December 2004. It is noteworthy that shortfinned eels recorded a summer CPUE of 8.73 from zone 9, which is a historical peak for the Birches Inlet rivers.

Captured eels ranged in size between 66 and 700 mm, with the majority of larger eels captured from reference zones.

Table 9.12. CPUE (standardised to fish per 1200 seconds) for *A. australis* in all river zones between December 2001 and April 2005. (* denotes stranded)

Zone	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	
Zone 1 river	2.22	0.20*	0.25	0.61	0.19	0.24	0	0.24
Zone 2 river	0.38	0.00	1.13	0.13*	0	0	0	0
Zone 3 river	1.99	0.97	2.86	0.73	0.97	0.26	2.12	1.53
Zone 4 river	4.05	3.56	0	0.33	2.18	1.86	4.66	1.95
Zone 5 river	5.19	6.32	2.26	7.57	3.89	1.25	3.52	2.91
Zone 7	0.38	4.52	1.92	0.95	12.93	0	2.79	-
Zone 8	1.06	3.58	1.98	0.96	1.29	0.72	3.25	0.46
Zone 9	1.86	2.19	2.80	3.15	4.81	0.45	8.73	0.48
Zone 13-14	0.88	0.77	0.28	2.39	0.28	0.29	1.11	0

9.4.3 Galaxiids and sandys

Table 9.13 to Table 9.16 provide summaries of catch effort data for galaxiids, sandys and grayling captured in Gordon River, Franklin River and their tributaries, Birches Inlet and Henty Rivers between December 2001 and April 2005. Summer catch rates were historically high, with several species returning record high catch rates in zones 4 – 5, river sites and tributary sites of zones 7, 8, 13 and 14. Additionally, climbing galaxias, spotted galaxias and sandys increased their range of distribution within the Gordon River, and Australian grayling were captured for the first time during the monitoring period.

*9.4.3.1 Climbing galaxias (*Galaxias brevipinnis*)*

A total of 121 climbing galaxias were captured during the December 2004 survey, which represents a total "across zone" CPUE of 2.78. Catches in April 2005 were significantly lower, with the capture of 28 fish returning total across zone CPUE of 0.52. The vast majority of fish were juveniles of less than 50 mm length, collected from zones 5, 7 and 13 indicating that the December sample coincided with a significant upstream migration run. Climbing galaxias returned the highest CPUE (12.08) of all zone 7 species sampled in December 2004.

Fish larger than 55 mm were found only in test and reference tributaries, specifically Ari Creek (zone 8), Indigo Creek and the Serpentine River (zone 1). It is noteworthy that climbing galaxias were collected from Indigo Creek in December 2004, but they were not collected from this zone 1 tributary site during April 2005. This absence requires further investigation. Climbing galaxias were electrofished in river zone 3 during the April 2005 survey, which is the first recoded occurrence of this species in this zone.

G. brevipinnis were absent from zone 8 catches in April 2005, which is consistent with results from previous surveys. Zone 7 could not be sampled in April 2005 due to high flows. Monitoring program results from these zones show a seasonal trend, with moderate to high catches during summer surveys followed by an absence of climbing galaxias from autumn catches. The summer surveys typically coincide with juvenile galaxiid migratory runs into the downstream reaches of the catchment.

*9.4.3.2 Spotted galaxias (*Galaxias truttaceus*)*

Spotted galaxias (*Galaxias truttaceus*) numbers were particularly high during the December 2004 survey. A total of 207 fish were captured, which equates to a total 'across zone' CPUE of 16.98 which was the highest for all species captured during this survey. Catches in April 2005 were also high; a total of 129 spotted galaxias were collected returning a total 'across zone' CPUE of 14.18.

Spotted galaxias were the most abundant species in river sites of zones 5 and 13 during the summer survey. Similarly this species was the most abundant in river sites of zones 4, 5 and 13 and tributary sites of zone 8 during April 2005. Catch rates in the Birches inlet zone were similar to those recorded in previous surveys.

Length frequency data for zones 4 and 5, and 13 and 14 showed strong juvenile recruitment in December 2004, with an increase in modal value of approximately 10 mm evident in the April 2005 data.

*9.4.3.3 Jollytails (*Galaxias maculatus*)*

A total of 64 *Galaxias maculatus* were captured during the summer survey, returning a mean 'across zone' catch rate of 1.11. Most were collected in zone 5, returning a CPUE of 10.18. Most of these fish were collected from site 44, and none were captured from tributary sites, which is consistent with past surveys. Jollytails were not collected from any site during the April 2005 survey.

*9.4.3.4 Tasmanian mudfish (*Neochanna cleaveri*)*

Five Tasmanian mudfish (*Neochanna cleaveri*) were collected from the lowest site in zone 13 (Henty u/s Bottle Creek) during the December 2004 survey, however it was not collected in the autumn survey. Although absent from earlier fish surveys, this species is becoming more common in catches from the lower Henty River.

*9.4.3.5 Sandys (*Pseudaphritis urvillii*)*

A total of 54 sandys were collected during summer and 33 during the autumn survey, representing a total 'across zone' CPUE of 0.94 and 0.62 respectively. Fish were captured in river sites of zones 3, 4, 5 and 7, and tributary sites of zones 3 and 4, which represents a range extension in comparison to previous surveys.

High catch rates relative to other species were recorded from the Birches Inlet zone, where *P. urvillii* recorded the highest CPUE for any species captured in this zone. This is consistent with previous samples. Summer catch rates were within historical levels, however autumn catches from the Henty River sites were uncharacteristically high.

*9.4.3.6 Australian grayling (*Prototroctes maraena*)*

A single Australian grayling (*Prototroctes maraena*) was captured from the lower Henty River during the summer monitoring . This is the first time that this species has been collected from any site during the Basslink Fish Monitoring Program. The 107 mm specimen was collected from amongst cobbles at the Henty @ Yolande site.

Australian grayling are listed as vulnerable under both the *Threatened Species Protection Act* 1995 and the *Environment Protection and Biodiversity Conservation Act* 1999.

Table 9.13. CPUE for galaxiids (*G. brevipinnis*, *G. maculatus*, *G. truttaceus*) and sandys (*P. urvillii*) captured in the Gordon River between December 2001 and April 2005.

Zone	Species	Dec-01	Apr-02		Mar-03	Nov-03	Apr-04	Dec-04	Apr-05
1 river	*G. brevipinnis*	0	0	0	0.61	0	0	0	0
2 river	All (galaxiids and sandys)	0	0	0	0	0	0	0	0
3 river	*G. brevipinnis*	0	0	0	0	0	0	0	0.19
	P. urvillii	0	0	0	0	0	0	0.19	0
4 river	*G. truttaceus*	0.81	0.64	0.77	0	0	0	4.30	7.79
	P. urvillii	0	0	0	0.33	0	0.62	0.36	0.65
	G. brevipinnis	0	0	0	0	0.31	0	1.08	0
	G. maculatus	0	0	0	0	0	0	0.72	0
5 river	*G. brevipinnis*	0	0.47	2.71	0.76	4.26	0	12.03	5.04
	G. maculatus	0.42	2.34	0.45	0.57	12.77	5.19	10.18	0
	G. truttaceus	4.98	3.98	3.39	3.03	7.22	1.61	17.39	6.21
	P. urvillii	2.91	2.34	1.81	0.76	2.23	1.79	4.44	0.58

Table 9.14. CPUE for galaxiids (*G. brevipinnis, G. maculatus, G. truttaceus*) and sandys (*P. urvillii*) captured in the Gordon River tributaries between December 2001 and April 2005.

Zone	Species		Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05
1 tribs	*G. brevipinnis*	8.07	1.75	1.30	2.60	3.12	0.35	3.93	0
2 tribs	All (galaxiids and sandys)	0	0	0	0	0	0	0	0
3 tribs	*G. truttaceus*	0	0.12	0	0	0	0	0	0
	P. urvillii	0.18	0	0	0	0	0	0.19	0
4 tribs	*G. brevipinnis*	0.28	0	0.38	0	0	0.19	0	0
	G. truttaceus	4.53	1.56	2.26	2.52	0.35	1.53	1.46	2.35
	P. urvillii	0.28	0.31	0	0.90	0.17	0	0	0.20
	G. maculatus	0	0	0	0	0.17	0	0	0

Table 9.15. CPUE for galaxiids (*G. brevipinnis, G. maculatus, G. truttaceus*) and sandys (*P. urvillii*) captured in the reference river zones between December 2001 and April 2005.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	
7 river	*G. brevipinnis*	3.43	0	3.83	0	5.96	0	12.08	-
	G. maculatus	0	1.51	2.88	0	0.99	0	0	-
	G. truttaceus	1.91	2.51	8.63	3.80	4.96	0	5.58	-
	P. urvillii	1.91	3.01	0.96	2.85	3.97	4.00	2.79	-
8 river	*G. brevipinnis*	1.33	0	1.54	0	2.25	0	2.32	0
	G. truttaceus	0.53	0.45	0.44	0	0.32	0	1.39	0.23
	P. urvillii	0.27	0.45	0.44	1.29	0.32	0	0.23	0
9 river	*G. brevipinnis*	0	0.31	0.40	0	0.44	0.45	0	0
	G. maculatus	1.86	0	7.60	0.45	2.19	0.45	1.09	0
	G. truttaceus	1.24	3.12	7.60	5.41	7.44	4.96	4.37	0.95
	P. urvillii	9.31	12.49	6.80	12.16	9.19	5.86	7.64	6.67
13-14	*G. brevipinnis*	0.44	0	4.55	0.60	0	0.29	4.17	0
	G. maculatus	1.32	1.03	0	2.98	0.28	3.24	0.83	0
	G. truttaceus	3.31	5.9	7.68	6.27	6.12	1.18	16.98	14.18
	P. urvillii	1.55	1.28	0.28	1.19	0	0.59	0.56	4.10
	N. cleaveri	0	0	0	0	0.28	0.29	1.39	0
	P. maraena	0	0	0	0	0	0	0.28	0

Table 9.16. CPUE for galaxiids (*G. brevipinnis*, *G. maculatus*, *G. truttaceus*) and sandys (*P. urvillii*) captured in the reference tributaries between December 2001 and April 2005.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05
8 tribs (Frank. u/s Big Fall)	*G. brevipinnis*	1.61	1.28	2.86	4.54	1.28	1.19	0.95	0.32
	G. truttaceus	4.02	2.87	1.43	0.60	7.00	2.08	2.53	4.22

9.5 Conclusions

Catch rates for brown trout were similar to previous surveys, dominating the total mean CPUE for the survey, and dominating catches in tributary sites of zones 2-4, river sites of zones 2-3, and the upper Henty river site. Redfin perch abundance was relatively low, and the species does not appear to have increased its distribution in the river, and remains absent from tributary sites.

Pouched lamprey ammocoetes were in moderate abundance during both summer and autumn surveys, whilst only a single short-headed lamprey was captured during April 2005. Pouched lamprey were collected from zone 2 river and tributary sites, re-confirming the species ability to negotiate the hydrological barrier of the Splits.

Short finned eels showed a wide distribution throughout the test and reference zones during the 2004-05 surveys. Summer catches were generally higher than those recorded in the autumn survey. Summer catch rates from the Birches Inlet sites were higher than those recorded for previous surveys.

Strong juvenile recruitment was evident in the summer galaxiids catches. Jollytails, climbing galaxias, and particularly spotted galaxias abundances were particularly high in the downstream reaches of the Franklin, Gordon and Henty Rivers. Jollytails were absent and climbing galaxias abundance declined significantly in the autumn survey, whilst juvenile spotted galaxias were still evident at the lower Gordon and Henty sites, reflecting the propensity of climbing galaxias to migrate further upstream into the catchment.

Tasmanian mudfish continued to be present at the downstream Henty River site during the summer sample, and a single Australian grayling was also collected from this site. This represents the first recorded occurrence of a listed fish species during the Basslink fish monitoring surveys.

10 Interdisciplinary linkages

The Gordon River Basslink Monitoring Program aims to determine the environmental variability and trends presently occurring downstream of the Gordon Power Station, for the disciplines discussed in previous sections of this report. This section briefly summarises some of the interactions between the disciplines.

10.1 Hydrological interactions

The hydrological regime influences all sites downstream of the power station. Power station-driven flow regulation tends to dominate the flow regime of the downstream sites with a pattern which is often substantially different from the natural flow regime. Seasonal tributary inflows mitigate this effect to an extent proportional to their flow volume and location in the catchment. In general, when there are major natural inflows, the Gordon Power Station operates less.

The hydrological regime is the primary driver of geomorphic processes. The interaction between hydrologic and geomorphic processes impacts on riparian vegetation through erosion (substrate stability), deposition (burying, light interception), inundation (for too long, or in the wrong season) and direct physical disturbance (shear, abrasion). Benthic algae would be subject to a similar range of impacts.

The hydrological regime directly impacts on benthic macroinvertebrates through habitat area, flow velocities, and stranding. Combined with water temperature, it influences the physiological responses of individual species.

The hydrological regime combined with topography and physical barriers may impede the movement of migratory fish species.

10.2 Water quality interactions

Impoundment and flow regulation have the effect of damping or eliminating diurnal and weather-driven temperature signals in discharged flow, although a fundamental seasonal signal remains (see section 3). This effect is likely to impact directly on macroinvertebrates and fish. It possibly has an impact on benthic algae, although this is likely to be less than the hydrological impact. The magnitude and extent of thermal regulation will depend on the relative proportions of regulated discharge and unregulated tributary inflows

The interaction between the Lake Gordon water quality, water level and the intake to the power station may be creating opportunities for the downstream translocation of lacustrine organisms under certain conditions. The impoundment experiences thermal and chemical stratification at the power station intake, which persists for much of the year. Under the present low lake levels, the intake is above the stratification level, so there are no chemical or thermal barriers to the entrainment of living organisms into the power station inflow. The effect of this interaction appears to have been to allow the movement of lake-dwelling organisms, such as macroinvertebrates and fish into the downstream environment.

10.3 Other interactions

Adverse impacts on algae may reduce available food and habitat for macroinvertebrates. Similarly, reduced abundance of macroinvertebrates is likely to affect fish and aquatic mammals. To some extent, a reduction in riparian vegetation will reduce the amount of organic material entering the riverine habitat, again reducing food resources for macroinvertebrates. On the other hand, increased tree-fall has the potential to improve the quantity of habitat and resources for macroinvertebrates and larger aquatic biota. Another ubiquitous factor is the predatory and competitive interaction between native and exotic fish species, especially brown trout.

On a broader scale, regional weather patterns (both seasonal and longer-term) will drive changes in most of the interactions already discussed.

10.4 Basslink Baseline Report

Interactions between disciplines are not necessarily discernible over a one-year timeframe hence their relatively brief treatment in this report. The Basslink Baseline Report will examine all of the monitoring information gathered over the past four years of the BMP and will include a comprehensive discussion and examination of interdisciplinary linkages through the development of a conceptual model of the processes and characteristics of the middle Gordon River.

The Basslink Baseline Report is due to be produced in early 2006.

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